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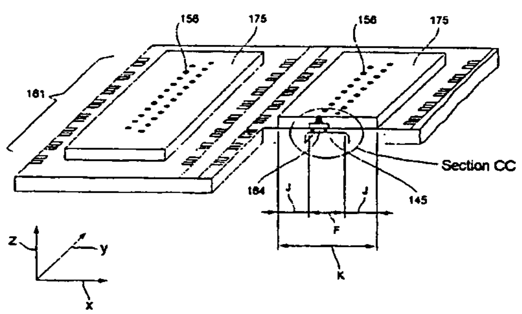

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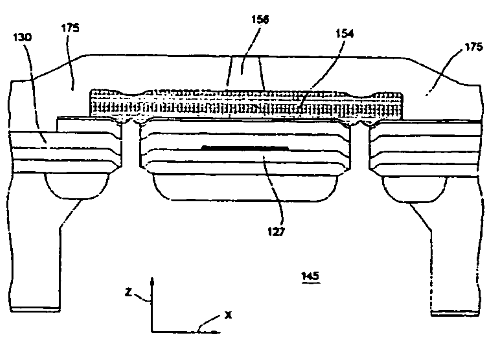

(57) Abstract: An actuating assembly (81) for ink jet printheads consists of a silicon die (161) and a structure (175), made monolithically in the same manufacturing process; the die (161) comprises microelectronics (162) and microhydraulics (163), in turn made of a lamina (164), a groove (145) and a plurality of channels (167); the structure (175) contains a plurality of chambers (157) and nozzles (156). The actuating assembly (81) is made via the operations of producing the microelectronics (162), cutting the groove (145), drilling the channels (167), growing a sacrificial metallic layer (154) and the structure (175), drilling the nozzles (156) and taking away the sacrificial layer (154).

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MONOLITHIC PRINTHEAD AND ASSOCIATED MANUFACTURING PROCESS

Technical Field – This invention relates to a printhead used in equipment for forming black and colour images, by way of successive scanning passes, on a print medium, normally though not exclusively a sheet of paper, using the thermal type ink jet technology, and more particularly to the actuating assembly of the head, and to the relative manufacturing process.

Background Art – Depicted in Fig. 1 is an ink jet printer with an indication of the parts of relevance for this invention. A fixed structure 41, a scanning carriage 42, four print heads 40 and an encoder 44 can be seen in the figure.

The printer may be a stand-alone product, or be part of a photocopier, of a "plotter", of a facsimile machine, of a machine for the reproduction of photographs and the like. The printing is effected on a physical medium 46, normally consisting of a sheet of paper, or a sheet of plastic, fabric or similar.

Also shown in Fig. 1 are the axes of reference:

x axis, horizontal, i.e. parallel to the scanning direction of the carriage 42; y axis, vertical, i.e. parallel to the line feeding direction; z axis, perpendicular to the x and y axes.

The composition and general mode of operation of a printhead according to the thermal type technology, and of the "top-shooter" type in particular, i.e. those that emit the ink droplets in a direction perpendicular to the actuating assembly, are already widely known in the sector art, and will not therefore be discussed in detail herein, this description instead dwelling more fully on some only of the features of the heads and their manufacturing process, of relevance for the purposes of understanding this invention.

Fig. 2 shows an enlarged perspective view of an actuating assembly 80 of a monochromatic ink jet printhead, consisting of a die 51 of a semiconductor material (usually silicon) on the upper face of which resistors 52 have been made for the emission of the ink droplets, driving circuits 53 for controlling the resistors 52, pads 54 for connecting the head to an electronic controller, not depicted in the figure, a resistive temperature sensor 65, reference marks 69, and which has a pass-through slot 55 along which the ink flows from a tank not shown in the figure. Attached to the upper face of the die 51 is a layer 60 of photopolymer having a thickness less than or equal to 25 μm wherein are made, using known photolithographic

techniques, a plurality of ducts 57 and a plurality of chambers 64 positioned in correspondence with the resistors 52. Stuck above the photopolymer 60 is a nozzles plate 61, usually made of a sheet of gold-plated nickel or of kapton, of thickness 50 μm or less, bearing a plurality of nozzles 62, each nozzle 62 being in correspondence with a chamber 64. In the current art, diameter of the nozzles is usually between 10 and 60 μm, while their centres are usually set apart by a step A of 1/150 or 1/300 of an inch (169 μm or 84.5 μm). Usually, though not always, the nozzles 62 are disposed in two parallel rows, staggered by a distance B = A/2, in order to double the resolution of the image in the direction parallel to the y axis, which accordingly becomes 1/300 or 1/600 of an inch.

Figure 2 shows the axes x, y and z, already defined with reference to Fig. 1.

The entirety of the driving circuits 53, called microelectronics in the following, is made typically by means of a simplified C-MOS/LD-MOS technology, having a low power dissipation and permitting a specific solution to be produced for each head model.

The traditional process for manufacture of the actuating assembly will now be described below in brief, with reference to the flow diagram of figure 4, starting from a first step 70 in which a wafer 66 is made available whereupon the dice 51 are made (figure 3). In a subsequent step 71, the wafer 66 is tested. In a step 72, the wafer 66 is coated with a layer of photopolymer, generally of the dry film type.

In a step 73 the photopolymer is exposed and, in a subsequent step 74, the chambers 64, in line with the resistors 52, and the ducts 57 are made in the layer of photopolymer 60 (figure 2), through development using known techniques. In a step 75 a protection is applied to the entire wafer and, in a subsequent step 76, the slots 55, which bring the ink to the ducts 57, are cut by way of a sandblasting operation. In a step 77, the protection is washed off and a sight check is made that the component is still whole.

In a subsequent step 100, the nozzles plates 61 are positioned in such a way that the nozzles 62 are aligned with the chambers 64, and stuck on the die 51 belonging to the wafer 66. Subsequently (step 101) the wafer 66 is applied to an adhesive tape 113 (figure 5), mounted on a frame 114. The individual dice 51 are separated in a step 102 by cutting with a diamond wheel 115, 50 ÷ 100 μm thick (figure 6), but are kept fast in their original positions by way of the adhesive tape

113 to which they adhere. Washing and drying are then performed (step 103), using an Ultratech machine for example.

In a step 105, a pick and place device of known technology, picks each die 51 off the adhesive tape 113 and places it with precision (error less than ± 10 μm on the x axis) on an alignment base. In a step 104, a multiplicity of flat cables 117 (figure 2) in the form of a continuous reel is supplied separately, each having a window 122 with fingers 123 that will be soldered to the connecting pads 54 of the dice 51, machine contact pads 121 and interconnecting tracks 120 which connect the pads 121 to the fingers 123. In a step 107 the flat cable 117 is aligned with the die 51, with a tolerance of ± 5 μm on the x and y axes.

In a step 110, an ultrasound soldering head comes into position above the connecting pads 54 of the die 51, whereto it solders one by one all the fingers 123 of the flat cable 117 by means of a technique known as point-to-point Tape Automatic Bonding (TAB).

In a subsequent step 111 the individual flat cables 117 are separated into distinct actuating assemblies 80.

In ink jet printheads the current technology is tending towards the production of a large number of nozzles per head (≥ 300), a definition higher than 600 dpi (dpi = "dot per inch"), a high working frequency (≥ 10 kHz) and the production of drops smaller (≤ 10 pl) than those of earlier technologies.

Requirements such as these make it necessary to produce actuators and hydraulic circuits of increasingly smaller dimensions, greater levels of precision, narrow assembly tolerances, and accentuate the problems generated by the different thermal expansion coefficients of the different materials of the head.

Great reliability is also required of the heads, especially when making provision for interchangeable ink tanks: the useful life of these heads, known as semi-fixed refill heads, is close to the printer life time.

Thus the need to develop and produce fully integrated monolithic heads, in which the ink channels, the selection microelectronics, the resistors and the nozzles are integrated in the wafer.

Obtaining such a result has been aided considerably by the low dimensions of the droplets, which are now of volumes less than 10 pl and require actuating energies of under 3 μj per actuator.

Various solutions have been proposed for producing heads with monolithic actuator, such as for example those described in the following patents:

US 5,850,241 "Monolithic print head structure and a manufacturing process therefor using anisotropic wet etching": the hydraulic structure of a head is obtained by etching the silicon anisotropically; the nozzles are made by means of an RIE etching on a membrane of SiO_2 a few micrometers thick, and in turn contain ring-shaped resistors for emission of the ink;

US 5,211,806 "Monolithic inkjet printhead": the hydraulic structure of a head is produced directly on the wafer using as a sacrificial layer a film of aluminium between 25 and 60 μm thick deposited by sputtering, and is made of nickel grown by means of an "electroless" process; the nozzles are etched at a later time in a chemical process on the said structure; the slot in the silicon for passage of the ink is cut by a laser;

US 4,894,664 "Monolithic thermal ink jet printhead with integral nozzle and ink feed" and US 4,438,191 "Monolithic ink jet printhead": the nozzles are made by means of electrolytic nickel grown on the wafer starting from a metallic layer, and by means of a photoresist sacrificial layer.

However the solutions revealed by these patents are extremely complex to realise, and in addition the techniques revealed by the first two have a yield that is both low and uncertain.

Disclosure of the Invention - The object of this invention is to produce an integrated head in which the ink channels and ducts, the chambers and resistors are made on a lamina comprising layers of inorganic material, and are produced partly by way of the process steps needed to produce the microelectronics, and partly by way of further process steps compatible with the process of integration of the microelectronics. Feeding of the ink from the tank takes place through holes made in the lamina in correspondence with each actuator. The ink ducts, the chambers and the ejector nozzles, called collectively the "microhydraulics", are produced by means of thick sacrificial metallic layers grown electrolytically and by means of structural layers of organic material, with a technology known as MEMS/3D structures (MEMS: Micro Electro Mechanical System).

Another object is to produce actuators and hydraulic circuits with lower dimensions and greater levels of precision.

Another object is to produce the nozzles directly on the wafer, obtaining a more precise alignment between said nozzles, the chambers and the resistors.

A further object is to reduce the problems generated by the different thermal coefficients of the different materials of the head actuating assembly.

Yet another object is that of avoiding hot soldering of the different parts of the actuating assembly, and consequently of avoiding misalignments between the nozzles plate and the actuators, due to the their different thermal expansions.

Another object is to avoid individual assembly of the nozzles plates on the wafer, or of a kapton reel with nozzles already drilled.

A further object is to make the two rows of nozzles closer together, in this way obtaining greater printing precision and lower encumbrance of the actuating assembly.

Yet another object is that of reducing the cost of producing the actuating assembly of the head, by eliminating the operations of sand blasting, photopolymerization, alignment and soldering of the nozzles plate. Elimination of the photopolymerization is additionally advantageous, since, with the reduction in dimensions of the actuating assembly, the photopolymer layer would have to be of very reduced thickness, and would accordingly be difficult to purchase and make.

A further object is to produce a further ink filter function by way of the holes made in the plate. The filter obtained in this way works in series with the filter already present in the cartridge, being finer than the latter filter on account of the low dimension holes.

Yet another object is to improve the efficiency of the actuating assembly production process, since this process is carried out entirely in a white room, where there is accordingly less risk of contamination from external particles.

The above objects are obtained by means of a monolithic printhead and relative manufacturing process, characterized as defined in the main claims.

These and other objects, characteristics and advantages of this invention will be apparent from the description that follows of a preferred embodiment, provided purely by way of an illustrative, non-restrictive example, and with reference to the accompanying drawings.

LIST OF FIGURES

Description of the Preferred Embodiment - An ink jet printhead 40 according to the invention comprises an actuator 81, illustrated in Fig. 7, which in turn comprises a structure 175 and a die 161. The structure 175 contains two rows of nozzles 156 parallel to the y axis. The die 161 comprises microelectronics 162 and soldering pads 177, permitting the electrical connection of the microelectronics 162 to the printer control circuits. Microhydraulics 163 belong partly to the structure 175 and partly to the die 161.

The process of manufacturing the actuator 81 for an ink jet printhead according to the invention comprises the production of a wafer 160, as indicated in Fig. 8, consisting of a plurality of dice 161.

In a first part of the process, the microelectronics 162 are produced and completed, and simultaneously, taking advantage of the same process steps and the same masks, the microhydraulics 163 are partly produced.

In a second part of the process, the microhydraulics 163 are completed by means of operations compatible with the first part of the process.

First part of process – The first part of the process will now be described with the help of Fig. 9, which represents a section view of the microelectronics 162, produced and completed during the first part, consisting of:

- a substrate 140 of silicon P, having resistivity preferably between 0.1 and 0.2 Ω·m and oriented with crystallographic axes {100};
- a diffused N-well layer 136, of a thickness preferably between 5 and 20 μm; this layer is not present if the microelectronics 162 are produced exclusively according to N-MOS technology;
- a layer 165 of Si_3N_4, made using LPCVD technology (LPCVD: Low Pressure Chemical Vapour Deposition), of a thickness preferably between 1000 and 2000 Å.
- a layer 135 of SiO_2 of thickness preferably between 0.8 e 1.5 μm, made, for instance, by way of the LOCOS technology, known to those acquainted with the sector art, performing the function of electric insulation between the electronic devices of the microelectronics 162;
- a layer 134, made of polycrystalline silicon, of thickness preferably between 0.4 and 0.6 μm, used as the gate electrode and for interconnection between the C-MOS and LD-MOS electronic circuits;
- a "P-body" layer 180;

- a diffused N+ layer 137 of silicon, of thickness preferably between 0.2 and 0.4 μm, performing the function of source and drain in the N-MOS and LD-MOS transistors;
- a P+ layer 183, needed for producing the P-MOS transistors and for connecting the "P-body" of each LD-MOS to the relative source;
- an interlayer 133 of BPSG (Boron Phosphorus Silicon Glass, i.e. SiO_2 doped with Boron and Phosphorous) of thickness preferably between 0.4 and 0.7 μm, produced by means of an LPCVD technology known to those acquainted with the sector art;
- a first metal 125 of Aluminium/Silicon, of thickness preferably between 0.5 and 0.7 μm, for interconnection of the active devices (C-MOS and LD-MOS);
- a second metal 131 of Aluminium/Copper, of thickness preferably between 0.5 and 0.7 μm, effecting the interconnection of the resistors with the drivers and the interconnection with the inputs and the outputs;
- an interlayer 132 between the first metal 125 and the second metal 131. The interlayer 132 is made of a layer of SiO_2 of thickness preferably between 0.8 and 1.2 μm produced, for example, by means of the TEOS technology, known to those acquainted with the sector art;
- a Tantalum/Aluminium resistor 127 of thickness preferably between 800 and 1200 Å, not depicted in this figure, but visible in the illustrations of the microhydraulics 163, starting from Fig. 12;
- a layer 130 for protection of the resistors, made of a layer of silicon nitride (Si_3N_4) upon which a layer of silicon carbide (SiC) is later overlaid, of total thickness preferably between 0.4 and 0.6 μm; and
- an anti-cavitation layer 126, made of a layer of Tantalum of thickness preferably between 0.4 and 0.6 μm, covered by a layer 172 of Gold of thickness preferably between 100 and 200 Å;

Also in Fig. 9, an upper face 170 and a lower face 171 are identified, and the directions of the x and z axes are indicated.

The first part of the manufacturing process of the actuator 81 according to the invention comprises the steps indicated in the flow diagram of Figs. 10a and 10b. The subsequent masks used are not depicted in the drawings, as they are not necessary for an understanding of the process.

In a step 201 the substrate 140 of silicon P is provided.

In a step 202, by means of a first mask, implantation of the Phosphorous and its subsequent diffusion are carried out to produce the N-well layer 136. Where the microelectronics 162 are made exclusively in N-MOS technology and do not therefore possess the N-well layer 136, this must still be done, as it is necessary for production of the microhydraulics 163, as will be described in relation to the second part of the process.

In a step 203, deposition of the lower layer 165 of Si_3N_4 is effected by way of LPCVD technology (Low Pressure Chemical Vapour Deposition). Simultaneously a layer of Si_3N_4 is deposited on the upper face as well, not indicated in the figure as it will be eliminated in a subsequent step.

In a step 204, by means of a second mask, the layer of Si_3N_4 on the upper face is etched, which will subsequently be used as a mask for effecting implantation of the Boron, by means of a technology known as "channel stop".

In a step 205, the field oxide (LOCOS) layer 135 is grown, again using as a mask the layer of Si_3N_4 etched on the upper face.

In a step 206 "dry etching" is performed of the layer of Si_3N_4 on the upper face, which in this way is eliminated.

In a step 207 implantation of the Boron is effected in the spaces left uncovered by the layer 135 of field oxide (LOCOS), i.e. in the active zones, for the purpose of regulating the threshold voltage of the C-MOS.

In a step 210 growth is effected of the "gate oxide", not shown in any of the figures, as not of relevance to this invention.

In a step 211 deposition is effected of the polycrystalline Silicon constituting the "gate" electrodes 134, and which may also constitute interconnections and dissipators arranged under the resistors 127.

In a step 212 the polycrystalline Silicon is etched using a third mask.

In a step 213, implantation of the Boron using a fourth mask and subsequent diffusion of the Boron to produce the "P-body" layer 180 take place.

In a step 214, by means of an implantation of Boron and the use of a fifth mask, the P+ layer 183 is produced, which constitutes the source and the drain of the P-MOS transistors and provides the connection between the "P-body" of the LD-MOS and the relative sources.

In a step 215, implantation is effected of the Arsenic using a sixth mask, with the purpose of producing the N+ junctions 137 of the sources and of the drains of the N-MOS and LD-MOS transistors.

In a step 216 the interlayer 133 of BPSG is made.

In a step 217 the interlayer 133 of BPSG is etched using a seventh mask, with the purpose of making the opening of the contacts.

In a step 220, the first metal 125 of Aluminium/Silicon is deposited.

In a step 221, photolithography and etching of the first metal 25 are performed using an eight mask.

In a step 222 the interlayer 132 (SiO_2 TEOS) is deposited between the first metal 125 and the second metal 131.

In a step 223, by means of a ninth mask, photolithography and etching of the interlayer 132 are performed, with the purpose of producing connection paths, called "vias" by those acquainted with the sector art, between the first metal 125 and the second metal 131.

In a step 224 the layer of Tantalum/Aluminium constituting the resistors 127 and the layer of Aluminium/Copper, constituting the second metal 131, are deposited.

In a step 225, by means of a tenth mask, photolithography of the second metal 131 is performed.

In a step 226, by means of an eleventh mask, photolithography of the Tantalum/Aluminium layer, with the purpose of producing the resistors 127, and etching of the second metal 131 are performed.

In a step 227, an in-process test is conducted on any devices arranged for process control.

In a step 230, the layer 130 of Si_3N_4 and of SiC, for protection of the resistors 127, is deposited.

In a step 231, the anti-cavitation layer 126 of Tantalum, covered by the layer 172 of Gold, is deposited.

In a step 232, photolithography and etching of the layer of Tantalum 126 and of the layer 172 of gold are performed using a twelfth mask.

Second part of the process – The second part of the manufacturing process of the actuating assembly 81 of a monolithic ink jet printhead, according to this invention, is specifically for obtaining the microhydraulics 163.

Depicted in Fig. 11 are two generic dice 161, belonging to the wafer 160, as they are at the end of the second part of the process. Also visible in this figure are the structures 175 and the nozzles 156. Two sections of the microhydraulics 163 are indicated: a section AA, parallel to the plane z-x, and a section BB, parallel to the plane x-y.

In Fig. 12 the sections AA and BB are enlarged.

In the section AA, the structure 175 can be seen, made of a layer of, for instance, polyamide or epoxy resin, of thickness preferably between 30 and 50 μm and containing:

- the nozzles 156, arranged in two columns parallel to the y axis;
- chambers 157, arranged in two columns parallel to the y axis; and
- ducts 153.

Only one of the nozzles 156 and only one of the chambers 157 can be seen in the section AA, as the two columns in which they are arranged are staggered with respect to one another. Also visible are:

- the substrate 140 of silicon P;
- a groove 145, having its greater dimension parallel to the y axis, and therefore to the columns of nozzles 156.

Also depicted in figure 12 is a lamina 164, consisting of all the layers that can be obtained without adding steps to those necessary for production of the microelectronics 162 described in the first part of the process. However, during the first part of the process, it may be decided not to make some of the layers in the lamina 164, with the purpose of optimizing some characteristics, such as for example:

mechanical robustness of the lamina 164; compensation of the residual forces of compression or traction between the different layers; mechanical rigidity of the lamina 164; and thermal dissipation of the lamina 164.

In particular the lamina 164 comprises:

- the N-well diffused layer 136 of Silicon, which, in the area of the microhydraulics 163, has the purpose of optimizing some mechanical characteristics of the lamina 164, such as for example: a greater mechanical robustness of the lamina 164; a lower sensitivity to lack of compensation of the residual forces of compression or traction between the various layers; a greater liberty of design of the lamina 164; a greater mechanical rigidity of the lamina

164, which reduces the width of the vibration modes excited by the emission of the droplets 184 of ink; and a greater thermal dissipation of the lamina 164. The same layer 136 also has the purpose of acting as a stop in the process of etching the groove 145 in the KOH bath ("electrochemical etch stop"), as will be described in step 244;

- the LOCOS SiO_2 insulating layer 135;
- the Tantalum/Aluminium resistor 127 of thickness 800 ÷ 1200 Å;
- the layer 134 of polycrystalline Silicon which, in the area of the microhydraulics 163, made in the form of localized areas, improves rigidity of the lamina 164, and, under the resistor 127, permits a faster cooling of the resistor 127 between one command pulse and the next;
- the N+ Silicon contact 137;
- the interlayer 133 of BPSG;
- the interlayer 132, made of a layer of SiO_2;
- the second metal 131 of Aluminium/Copper;
- the layer 130 of Si_3N_4 and of SiC for protection of the resistors;
- channels 167; and

-the anti-cavitation layer 126, consisting of a layer of Tantalum covered by a layer of Au 172, which in this invention also has the function of "seed layer"; the segments 124 which cover entirely the bottom of each chamber 157 belong to this layer.

Illustrated by way of example in Fig. 13 is a variant of the invention, in which each of the chambers 157 is fed by a number of channels 167 and ducts 153 greater than two, for example four.

The second part of the process will now be described in which the microhydraulics 163 of the actuator 81 are produced, with the aid of the flow diagram of Fig. 14a and Fig. 14b.

In a step 241, the wafer 160 as it results at the end of the first part of the process is available (step 232 of the flow diagram of Fig. 10b), finished in the areas of the microelectronics 162, protected by the continuous layer 130 of Si_3N_4 and SiC, and ready for the subsequent operations in the areas of the microhydraulics 163, as may be seen in Fig. 15, restricted to an area about a single resistor 127. The microhydraulics 163 do not necessarily comprise all of the layers produced in the microelectronics 162: in the non-restrictive example of the figure, it comprises only

the substrate 140 of silicon P, the N-well layer 136, the LOCOS layer 135 of SiO_2, the TEOS interlayer 132 of SiO_2, the Tantalum/Aluminium resistor 127, the layer 130 of Si_3N_4 and SiC for protection of the resistors, the layer 126 of Tantalum, covered by the layer 172 of Gold, etched according to the known technology, and the LPCVD layer 165 of Si_3N_4.

In the microhydraulics 163 there are the zones 146, prepared for subsequent drilling, from which the N-well layer 136 and the LOCOS SiO_2 layer 135 are missing. To obtain the condition where the N-well layer 136 is missing, the first mask was used in the step 202, which avoided the implantation of the phosphorous in the zones 146, whereas to ensure the lack of the LOCOS SiO_2 layer 135, the layer of Si_3N_4 on the upper face was used with the mask function in the step 204, which avoided the growing of the SiO_2. In these zones 146, the layer 126 of Tantalum, covered by the layer 172 of Gold, has holes produced by means of the etching described in step 232.

In a step 242, an under layer 143 of photoresist, of thickness preferably between 8 and 10 μm, is applied to the layer 165; exposure is effected with a thirteenth mask, followed by development. At the end of this operation, a lower window 44 of width L is obtained in the bottom photoresist layer 143, through which the LPCVD Si_3N_4 layer 165 is removed, by way of the technology known as "plasma dry etching".

In a step 243, the groove 145 is etched through a lower window 144, by way of "dry" type ICP technology ("Inductively Coupled Plasma"), known to those acquainted with the sector art, as illustrated in Fig. 16. The groove 145 has the same width L as the lower window 144, has walls substantially parallel to the z axis and a depth T of approximately 500 μm. With a speed of between 10 and 20 μm/min, the etching time is between 25 and 50 minutes.

The photoresist of the lower layer 143 has selectivity roughly 75:1 with respect to Silicon. This means that the photoresist removal speed is 1/75 of that of the Silicon: in the time in which the Silicon is etched to a depth T, for example of 500 μm, the thickness of the photoresist is reduced by about 500 μm/75 = 6.7 μm.

Finally the residue of the lower layer 143 of photoresist is removed, while the part of the LPCVD Si_3N_4 layer 165 outside the lower window 144 remains.

In a step 244, etching of the groove 145 through the lower window 144 is continued by means of a "wet" technology using, for example, KOH (Potassium

Hydroxide) or TMAH (Tetrametil Ammonium Hydroxide), as is known to those acquainted with the sector art. Etching of the groove 145 is conducted according to geometric planes defined by the crystallographic axes of the Silicon, as illustrated in Fig. 17, and accordingly forms an angle $\alpha = 54.7°$.

At the end of this operation, a lamina 164 is identifiable which includes, in the non-restrictive example of the figure, the resistor 127 and the layers included between layer 136, N-well, and layer 126, of Tantalum covered by a layer 172 of Gold.

Provided below is an example of calculation of the dimensions, tolerances and the work times for the various etchings. Given for example the following nominal values:

- thickness of the wafer 160 before growing of the various layers, $W = 625\ \mu m$;
- combined thickness of the N-well layer 136 plus half of the insulating layer 135, $G = 9\ \mu m + 1\ \mu m = 10\ \mu m$;
- depth of the dry etching, $T = 500\ \mu m$; and
- width at the end of the wet etching, $F = 220\ \mu m$,

the necessary wet etching depth is

$$E = W - G - T = 115\ \mu m$$

With a speed of about 1 μm/min, the time needed for the wet etching is about 115 minutes. The width L of the lower window 144 is :

$$L = F + 2\,E / \tan\alpha = 220\ \mu m + 2 \cdot 115\ \mu m / 1{,}412 = 383\ \mu m.$$

When we include in our calculation the following tolerances, assumed by way of example:

- width L of the lower window 144: tolerance ± 2 μm;
- thickness W of the wafer 160: tolerance ± 15 μm;
- thickness G: tolerance ± 1 μm;
- depth T of the dry etching: tolerance ± 10 μm;

the following maximum and minimum values for depth of the wet etching are obtained:

$$E_{min} = W_{min} - G_{max} - T_{max} = (610 - 11 - 510)\ \mu m = 89\ \mu m$$

$$E_{max} = W_{max} - G_{min} - T_{min} = (640 - 9 - 490)\ \mu m = 141\ \mu m$$

and finally the following nominal, minimum and maximum values are obtained for the width F at the end of wet etching:

$$F_{nom} = L - 2\,E / \tan\alpha = 383\ \mu m - 2 \cdot 115\ \mu m / 1{,}412 = 220\ \mu m.$$

$F_{min} = L_{min} - 2\ E_{max} / \tan\alpha = 381\ \mu m - 2 \cdot 141\ \mu m / 1{,}412 = 181\ \mu m.$

$F_{max} = L_{max} - 2\ E_{min} / \tan\alpha = 385\ \mu m - 2 \cdot 89\ \mu m / 1{,}412 = 259\ \mu m.$

During this operation, the N-well layer 136 is electrically polarized with positive polarity; a Platinum counter-electrode, immersed in the KOH bath, is negatively polarized; this process belongs to the known art, and comprises the use of a third reference electrode. The surface of separation between the N-well layer 136 and the substrate 140 of silicon P constitutes an inversely polarized junction that stops the passage of current: in this way, the etching proceeds like a normal chemical etching in a KOH bath. When the etching reaches the surface of separation, it destroys the junction and allows the passage of a current from the N-well layer 136 to the Platinum counter-electrode, immersed in the KOH bath. The current, by electrolytic effect, generates a layer of insulating oxide SiO_2, resistant to attack by the KOH bath, which stops continuation of the etching. This method, known as "electrochemical etch stop", is known to those acquainted with the sector art and acts as a way of stopping the etching process when this comes to the predetermined surface that separates the N-well layer 136 from the substrate 140 of silicon P.

The step 244 is continued in time until all the surfaces of the N-well layer 136 present on the wafer 160 have surely been reached by the etching.

In the areas located in correspondence with the preparations 146, there is no N-well layer 136, and accordingly the electrochemical etch stop will also be missing. In these areas, etching continues until it meets with the TEOS SiO_2 layer 132, which resists attack from the KOH bath.

In a step 245, described with the aid of Fig. 18, a masking layer 147 of positive photoresist, of thickness preferably between 1 and 3 μm, is applied to the upper face 170. Exposure and development are effected to produce windows 150 in the masking layer 147 of photoresist, in correspondence with the preparations 146.

In a step 246, by way of the "dry etching" technology known to those acquainted with the sector art, the various layers are etched in correspondence with the windows 150, in such a way as to obtain channels 167 visible in Fig. 19, having a diameter preferably between 5 and 12 μm. In this operation the layer of Tantalum 126 performs the function of etching mask. Finally the masking layer 147 of photoresist is taken off.

The ink container, not visible in any of the figures as it is not essential for the understanding of this invention, is normally provided with a filter suitable for retaining impurities present in the ink 142. The channels 167 can be made with a lesser diameter than the characteristic dimension of the pores of said filter, so that they can retain any impurities that get away from the filter. The feeding to the chambers 157 is still guaranteed as the channels 167 are more than one for each chamber, and the probability of one of these being obstructed in the lifetime of the head is very low.

In a step 247, described with the aid of Fig. 20, an upper layer 151 of photoresist, of thickness preferably between 10 and 25 μm, is applied to the upper face 170. Said photoresist may be positive, for instance AZ 4500 (Hoechst) or STR 1000 (Shipley), or negative, for instance EPON SU-8 epoxy type (Shell Chemical) or Probimide 7020 (CIBA). Exposure using a fourteenth mask and subsequent development are performed to produce an upper window 152 which extends above the channels 167, as can be seen in Fig. 21.

In a step 250, post baking of the upper layer 151, to render it resistant to subsequent operations, and cleaning of the upper window 152 are performed by means of plasma etching in Oxygen, which burns the organic residues and chemically activates the Gold in the layer 172 covering the Tantalum of the layer 126, in order to promote the operation described in the next step.

In a step 251, described with the aid of Fig. 22, electro-deposition of electrolytic Copper is performed in the upper window 152, in such a way as to form a sacrificial layer 154, of thickness substantially equal to that of the upper layer 151 of photoresist. The chemical activation of the Gold surface, referred to in the previous step, permits the start of deposition of Copper that is uniform over all the surface constituting the bottom of the upper window 152, and simultaneous on all the dice 161 belonging to the wafer 160.

The electrolytic Copper is deposited only in correspondence with the upper window 152 as the latter is in communication with the layer 126, which forms a conducting and equipotential surface electrically connected to a voltage having a value in function of the parameters of the bath, whereas all the remaining surfaces are covered by the upper layer 151 of photoresist.

The composition of the electrolytic bath and the relative additives are selected in such a way as to obtain a horizontal growth factor, i.e. parallel to the x and y

axes, substantially equal to the vertical growth factor, i.e. parallel to the z axis, in such a way that, after a vertical growth substantially equal to the thickness of the upper layer 151 of photoresist, the area above the channels 167 is entirely covered by the copper. The upper surface of the copper grown in correspondence with the channels 167 is only partly planarized; the greater the thickness of copper employed, the better the planarization.

The sacrificial layer 154 may be made using a metal other than copper, for example Nickel or Gold. The electrolytic bath may contain, for example, Cu sulfonate pentahydrate, for depositing the Copper, or Ni sulfonate tetrahydrate, for depositing the Nickel, or non-cyanide pure gold (Neutronex 309), for depositing the Gold.

The electrolytic metal depositing process, such as that described, is preferred to the chemical type depositing processes, commonly called "electroless", as it has a greater deposition speed, greater depositing uniformity, the possibility of producing thicknesses of tens of μm, instead of only a few μm, and is also easier to control.

Sometimes it may be necessary to produce a more complex shaped sacrificial layer 154', such as for instance that illustrated in Fig. 23. In this case, the steps 247, 250 and 251 have to be repeated, indicated here as 247', 250' and 251'.

In the step 247' a further layer 151' of photoresist is applied on the layers 151 and 154. Exposure using a fifteenth mask and subsequent development are performed to produce a further window 152', not shown in the figure, which extends at least in part above the sacrificial layer 154.

In the step 250', post-baking of the layer 151' and cleaning of the upper window 152' are performed by means of plasma etching in Oxygen.

In the step 251' more electrolytic Copper is electro-deposited in the window 152', so as to complete the sacrificial layer 154'.

If the shape of the sacrificial layer 154' is even more complex than that indicated in Fig. 23, the steps 247', 250' and 251' may be repeated various times, using a different mask each time.

Some considerations are now made regarding the seed layer 172 made up of the thin layer of Gold covering the layer of Tantalum 126 and having the purpose of encouraging the electrolytic growing of the Copper.

In general, a seed layer must have a low electric resistivity ($\leq 1\ \Omega/\square$), must guarantee a discrete adhesion to the layer underneath, and must not oxidise to

facilitate the deposition of the upper layer in growing. It must also be easy to remove.

A film of Cr/Au (of thickness 100 Å + 200 ÷ 300 Å) or similar could be used for the purpose, but this would require a further step of evaporation, and the installation of a relative "sputtering" plant. In addition, this type of seed layer would have to be removed at the end of the process.

In this invention on the other hand, by way of a non-restrictive example, the use is proposed of the Gold covering 172 as the seed layer, as already described. This solution has the advantage of not requiring additional process steps. In addition, the seed layer thus obtained has an electric resistivity in the region of 1 Ω/□ (including the contribution of the layer of Tantalum 126 in parallel), does not oxidize easily and is easy to remove, if necessary.

In a step 252, the upper layer 151 of photoresist is taken off, and also - where applicable - the further layer 151', as illustrated in Fig. 24.

In a step 253, a structural layer 155 is applied on the upper face 170 of die 161, as illustrated in Fig. 25, by means of a centrifuge, in a known process called "spinner coating". The structural layer 155 is preferably between 25 and 60 μm thick, and consists of negative photoresist, of the epoxy type (for example, EPON SU-8 by Micro Chemical Corporation) or polyamide type (for example, Probimide 7020 by Olin Hunt).

In a step 254, illustrated with the aid of Fig. 26, the structural layer 155 is subjected to "prebaking" at 100 °C, and subsequently to exposure with a sixteenth mask that covers the areas 156a, corresponding to the future nozzles 156, the areas 177a, which contain the pads 177, and the heads 181 of the die 161. The same mask, on the other hand, leaves an area 175a uncovered.

In a step 255, illustrated with the aid of Fig. 27, development of the area 175a is effected, during which the nozzles 156, having a diameter preferably between 15 and 30 μm, are opened and the areas 177a and the heads 181 are freed of the photoresist. In this way, of the structural layer 155 only a structure 175 remains. In Fig. 27 a section CC of the structure 175, of the lamina 164 and of the groove 145 is identified and enlarged, as it is at this stage of the work.

With this operation, the nozzles 156 can, with great precision, be aligned with respect to the resistors 127 and be parallel to the z axis. This precision is maintained also during subsequent operations.

In addition, the adhesion between the structure 175 and the layer 130 of SiC is guaranteed by a very strong chemical link, deteriorating with difficulty in time and on contact with the ink.

On this subject, it is recalled that the technology of the known art provides for soldering of the nozzles plate 61 on the layer of photopolymer 60, with resultant alignment difficulties and with the risk of deforming the plate 61 on account of the heat and pressure applied during this soldering. Also the known technology has at least two soldering interfaces which are more permeable to the ink, since they are made between materials having different coefficients of thermal expansion and soldered together with difficulty.

The structure 175 is designed in such a way as to present the least covering possible on the individual die 161, with the purpose of reducing the mechanical tension and bridging of the wafer 160 after complete polymerization, described in the next step. In addition, the structure 175 must adhere, on both sides, to a zone where the die 161 is sufficiently thick as to guarantee the assembly the required mechanical robustness, and therefore must protrude beyond the sides of the lamina 164 by an interval J, which in practice may assume a value of, for example, 500 μm.

The structure 175 therefore has a width K of

$$K = F + 2J$$

where F is the width of the lamina 164, already defined with the aid of Fig. 17.

In a step 256, the structure 175 is hard-baked in order to obtain complete polymerization.

A temperature of, for example, 200 °C is used, if the structure 175 is made of EPON, or of 300 ÷ 400 °C in Nitrogen, if the structure is made of Probimide, which is transformed into Polyamide.

With this operation, the structure 175 acquires considerable hardness together with great mechanical and chemical resistance. It also becomes impermeable to ink, avoiding any of the successive phenomena known by the sector experts as swelling.

Following the hard baking, a very slow cooling is performed.

In a step 257, cleaning is finally performed of the structure 175 and of the nozzles 156 by way of a plasma etching in a mix of Oxygen and CF_4, which burns

organic residues and chemically prepares the Copper of the sacrificial layer 154, with the purpose of promoting the operation described in the next step.

In a step 260, the sacrificial layer 154 is removed by a chemical attack made by means of a chemical bath already formulated, such as for example a solution of HCl and HNO_3, the turnover of which is encouraged by the channels 167 and by the nozzles 156, and if necessary by ultrasound agitation or by a spray jet. At the end of this operation, the ducts 153 and the chamber 157 are formed, the shape of which repeats exactly the sacrificial layer 154, as can be seen in Fig. 28.

While the sacrificial layer 154 is being removed, the wafer 160 is in part protected by the structure 175, and, where this does not exist, by the layer of protection 130 of Si_3N_4 and SiC.

In a step 261, etching is performed of the layer 130 of Si_3N_4 and SiC in correspondence with the soldering pads 177, so that the latter may subsequently be soldered to the fingers 123 by means of a known technology such as TAB. To selectively etch the layer 130, a specific mask would be necessary, but here a more simple technique is illustrated, in a non-restrictive way, and which consists in using the layer of Tantalum 126 covered by the layer 172 of Gold with a mask function. For this purpose, with the twelfth mask used in the step 232, the anti-cavitation layer 126 is given the shape indicated by the dot and dash area in Fig. 29, which leaves the pads 177 uncovered.

The layer 126 is divided into segments 124, each of which must have dimensions such as to cover with certainty the entire bottom of a corresponding chamber 157, but must protrude as little as possible outside the chamber, with the purpose of leaving the greatest area available for the adhesion between the structure 175 and the underlying layer 130 of SiC: in practice, each segment 124 protrudes beyond the edge of the corresponding chamber 157 by a few micrometers, enough to compensate the manufacturing tolerances.

Finally, in a step 262 the following operations, known to those acquainted with the sector art, are carried out:

- cutting of the wafer 160 into the single dice 161;
- soldering of the flat cable 117 on each die 161 through the TAB process, for the purpose of forming a subassembly;
- mounting of said subassembly on the container of the head;
- filling of the ink 142;

- testing of the finished head 40.

2^{nd} **Embodiment** – This embodiment is described with the aid of the flow diagram of Fig. 30 and of the Figs. 31, 32, 33 and 34. After performing the step 252, already described and illustrated in the flow diagram of Fig. 14, the process continues to step 270, in which a complementary, positive type photoresist, preferably between 25 and 60 μm thick, is applied to the upper face 170 of the die 161.

In a step 271, the following operations are performed in sequence: an exposure by way of a seventeenth mask, complementary to the sixteenth, a development and a soft-baking at 80°C of the complementary photoresist. Following these operations, as may be seen in the sectioned axonometric projection of Fig. 31, a frame 173 is obtained that covers the areas of the soldering pads 177 and the heads 181 of the adjacent die 161, and which encloses the bays 174. In this figure, the grooves 145 and the sacrificial layers 154, which in this phase of manufacturing are uncovered, can be seen.

In a step 272, a semiflexible, transparent resin is placed in the bays 174, for example an epoxy resin, of the Stycast type produced by Emerson Cunning, or polyamide resin, of the EPO-TEK 600 type produced by Epoxy. This may be done by using, for example, a multiple volumetric doser, or a serigraphing process with rheometric pump, such as for example the Rheometric Pump Print Head produced by MPM, or an extrusion process by means, for example, of the Extrusion Coater model FAS-COAT produced by FAS Technology Corp., in such a way that the bays 174 are filled up to the upper level of the frame 173.

In a step 273, a thermal pre-polymerization is effected of the semiflexible epoxy or polyamide resin filling the bays 174, at a temperature ≤ 80 °C in order not to excessively harden the photoresist constituting the frame 173.

In a step 274, the frame 173 is removed by means of a solvent associated with the photoresist selected, with a known "lift off" process. The semiflexible resin that fills the bays 174, on the other hand, remains unaltered; the resin structures 178 visible in Fig. 32 are obtained in this way. A section DD corresponding to the lamina 164 as it is at the end of this step, is enlarged in Fig. 33.

In a step 275, a complete polymerization of the semiflexible resin making up the structures 175 is effected.

In a step 276 (Fig. 34), drilling is performed with an excimer laser to produce, through an eighteenth mask, the nozzles 156. The drilling stops spontaneously when it reaches the sacrificial layer 154 of metal.

In a step 277, cleaning of the nozzles 156 is performed in an Oxygen + CF_4 plasma, as already described, during which the waste left after the laser drilling is eliminated, both from the entrance edge of the nozzles, and from the surfaces of the sacrificial layers 154. Also cleaned during this operation are the areas 176 left uncovered after the lifting-off of the frame 173.

At the end of this operation, the section corresponding to the lamina 164 looks as illustrated in Fig. 34, with the sacrificial layer 154 inspectable as the resin structure 178 is transparent.

By appropriately focussing the laser beam, it is possible to produce the nozzle 156 with a cylindrical or truncated cone shape having its greater base in contact with the sacrificial layer 154.

The operations continue according to the flow diagram of Fig. 14, with lifting-off of the sacrificial layer 154 (step 260).

3rd **Embodiment** – This embodiment is described with the aid of the flow diagram of Fig. 35 and of Fig. 36.

After performing the step 246, already described and illustrated in the flow diagram of Fig. 14, the process continues with step 280, in which a negative photoresist, for example Waycoat SC 900 (Olin Hunt), or a positive photoresist, for example PMMA type, of thickness preferably between 3 and 4 μm, is applied to the layer 130 of SiC, with which it has a strong adhesion.

In a step 281, an ejectors plate 141 is prepared consisting of a sheet of kapton preferably 50 μm thick and provided with ejectors 158, which include the functions that, in the preferred embodiment, were assured by the chambers 157, the ducts 153 and nozzles 156. The ejectors plate 141 may have an "inorganic adhesion promoter" layer, made for instance of SiC of thickness preferably between 200 and 800 Å, or a layer of adhesive of thickness preferably between 5 and 15 μm, on the face that will be stuck to the photoresist deposited on the layer 130, for the purposes of improving the adhesion.

In a step 282, using a nineteenth mask, exposure of the negative photoresist is effected. This is followed by development, at the end of which only the areas where

the nozzles plate will be stuck are still covered by photoresist. The resistors 127, the channels 167 and the soldering pads 177 are all uncovered.

In a step 283, the ejectors plate 141 is aligned and soldered to the photoresist deposited on the layer 130, giving the actuating assembly 81' seen in cross section in Fig. 36.

Using this method the ejectors plate 141 remains stuck on a flat surface, and subsequently the axis of the individual nozzles remains perpendicular to the upper face 170 of the die 161. On this subject, it is recalled that in the known art, on account of the discontinuity of the support plane, at the end of the sticking operation the axes of the nozzles are not perpendicular to said face 170.

In short, without prejudice to the principle of this invention, the construction details and the embodiments may be abundantly varied with respect to what has been described and illustrated, without departing from the scope of the invention.

CLAIMS

1. Thermal ink jet printhead (40) for the emission of droplets of ink on a print medium (46) through a plurality of nozzles (156), comprising an ink tank (142) and an actuating assembly (81) provided with a die (161) with an upper face (170) and a lower face (171), said die (161) in turn comprising a substrate (140), **characterized in that** said die (161) has a monolithic construction comprising:

- a groove (145) in fluid communication with said ink (142) and made in said substrate (140) in correspondence with said lower face (171);
- a plurality of channels (167) in fluid communication with said groove (145);
- a plurality of resistors (127).

2. Printhead according to claim 1, **characterized in that** said die (161) comprises a lamina (164), produced monolithically on said die (161), placed in contact with said groove (145) and in turn comprising said channels (167) and said resistors (127).

3. Printhead according to claim 2, **characterized in that** said lamina (164) is made of layers of inorganic material.

4. Printhead according to claim 2, **characterized in that** said lamina (164) is between 1 and 50 μm thick.

5. Printhead according to claim 2, **characterized in that** said channels (167) have a diameter of between 5 and 12 μm.

6. Printhead according to claim 2, **characterized in that** said lamina (164) comprises a layer (134) of polycrystalline silicon in thermal contact with at least one of said resistors (127).

7. Printhead according to claim 1, **characterized in that** said lamina (164) comprises an N-well layer (136).

8. Printhead according to claim 1, **characterized in that** said actuating assembly (81) comprises a structure (175) made of photoresist, in turn comprising:

- said plurality of nozzles (156);
- a plurality of chambers (157), each in thermal contact with each of said resistors (127) and in fluid communication with at least one of said channels (167) and with at least one of said nozzles (156).

9. Printhead according to claim 8, **characterized in that** said structure (175) is made of negative epoxy photoresist.

10. Printhead according to claim 8, **characterized in that** said structure (175) has a width (K), that said lamina (164) has a width (F), and that the value of the difference K - F is between 1 and 10 μm.

11. Printhead according to claim 1, **characterized in that** said actuating assembly (81) comprises a resin structure (178), in turn comprising:

- said plurality of nozzles (156);
- a plurality of chambers (157), each in thermal contact with each of said resistors (127) and in fluid communication with at least one of said channels (167) and with at least one of said nozzles (156).

12. Printhead according to claim 11, **characterized in that** said resin structure (178) is made of epoxy resin.

13. Printhead according to claim 11, **characterized in that** said resin structure (178) is made of transparent resin.

14. Printhead according to claim 11, **characterized in that** said resin structure (178) is made of semiflexible resin.

15. Printhead according to claim 1, **characterized in that** said actuating assembly (81) comprises an ejectors plate (141), in turn comprising:

- a plurality of ejectors (158), each in fluid communication with at least one of said channels (167) and in thermal contact with each of said resistors (127).

16. Printhead according to claim 15, **characterized in that** said ejectors plate (141) is made of kapton.

17. Process for the manufacture of an actuating assembly (81) for a thermal ink jet printhead (40), comprising the step of:

- providing a wafer (160) containing a plurality of dice (161), each of which contains a substrate (140), at least a microelectronics (162), a plurality of resistors (127), a plurality of soldering pads (177), an anti-cavitation layer (126), and a protection layer (130), said dice (161) having an upper face (170) and a lower face (171),

characterized in that it further comprises the steps of:

- (243, 244) making a groove (145) in said substrate (140) on said lower face (171) of each of said dice (161);
- (245) applying a masking layer (147) of photoresist on said upper face (170) of each of said dice (161) and producing a plurality of windows (150) in said masking layer (147);

- (246) performing a drilling of channels (167) through each of said windows (150) and lifting off said masking layer (147) of photoresist;
- (247) applying an upper layer of photoresist (151) on said upper face (170) of each of said dice (161), and producing a plurality of upper windows (152) on said upper layer of photoresist (151), each of said upper windows (152) being in correspondence with each of said resistors (127) and being shaped in such a way as to cover the corresponding resistor (127) and at least one of said channels (167);
- (251) depositing a plurality of sacrificial layers (154) inside each of said upper windows (152);
- (252) lifting off said upper layer (151) of photoresist;
- (253) applying a structural layer (155) on said upper face (170) of each of said die (161) and on said sacrificial layers (154);
- (255) producing a plurality of nozzles (156) on said structural layer (155), each of said sacrificial layers (154) being in correspondence with at least one of said nozzles (156);
- (260) lifting off said sacrificial layer (154);
- (261) etching said protection layer (130) in correspondence with said soldering pad (177).

18. Process according to claim 17, **characterized in that** said groove (145) is produced in a dry etching step and a wet etching step.

19. Process according to claim 17, **characterized in that** said structural layer (155) is made of epoxy or polyamide type photoresist.

20. Process according to claim 17, **characterized in that** said step (261) of etching said protection layer (130) in correspondence with said soldering pad (177) is effected using as the mask said anti-cavitation layer (126).

21. Process according to claim 17, **characterized in that** said step of:

- (251) depositing a plurality of sacrificial layers (154) inside each of said upper windows (152);

is followed at least once by further steps of:

- (247') applying a further layer of photoresist (151') on said upper layer (151) and on said sacrificial layers (154), and producing a plurality of further windows (152') in said further layer of photoresist (151'), each of said further

windows (152') overlapping at least in part with each of said sacrificial layers (154);

- (251') depositing a further plurality of sacrificial layers (154') inside each of said further windows (152').

22. Process according to claim 17, **characterized in that** said nozzles (156) are made by means of photolithography.

23. Process according to claim 17, **characterized in that** said sacrificial layer (154) is made of metal.

24. Process according to claim 23, **characterized in that** said sacrificial layer (154) is made of copper, or nickel, or gold.

25. Process according to claim 17, **characterized in that** the steps of:

- (253) applying a structural layer (155) on said upper face (170) of each of said die (161) and on said sacrificial layers (154);
- (255) producing a plurality of nozzles (156) on said structural layer (155), each of said sacrificial layers (154) being in correspondence with at least one of said nozzles (156);

are substituted by the steps of:

- (270, 271) applying and etching a complementary frame (173) on said upper face (170) of each of said die (161), said complementary frame (173) being shaped so that said sacrificial layers (154) remain uncovered;
- (272, 273) applying and pre-polymerizing a resin on said upper face (170) of each of said die (161) and on said sacrificial layers (154), in the bays (174) left uncovered by said complementary frame (173);
- (274) lifting off said complementary frame (173);
- (275) producing resin structures (178) by means of the polymerization of said resin;
- (276) producing a plurality of nozzles (156) on each of said resin structures (178), each of said sacrificial layers (154) being in correspondence with at least one of said nozzles (156);

26. Process according to claim 25, **characterized in that** said complementary frame (173) is removed by means of a "lift-off" operation.

27. Process for the manufacture of an actuating assembly (81) for a thermal ink jet printhead (40), comprising the step of:

- providing a wafer (160) containing a plurality of dice (161), each of which contains at least a microelectronics (162) and a substrate (140), said dice (161) having an upper face (170) and a lower face (171),

characterized in that it further comprises the steps of:

- (243, 244) making a groove (145) in said substrate (140) on said lower face (171) of each of said die (161);
- (245) applying a masking layer (147) of photoresist on said upper face (170) of each of said die (161) and producing a plurality of windows (150) in said masking layer (147);
- (280) applying a layer of negative photoresist on said upper face (170);
- (281) preparing an ejectors plate (141) containing a plurality of ejectors (158);
- (282) exposing and developing said layer of negative photoresist;
- (283) soldering said ejectors plate (141) to said layer of negative photoresist.

28. Process according to claim 27, **characterized in that** said ejectors plate (141) is soldered to a flat surface.

Fig. 1

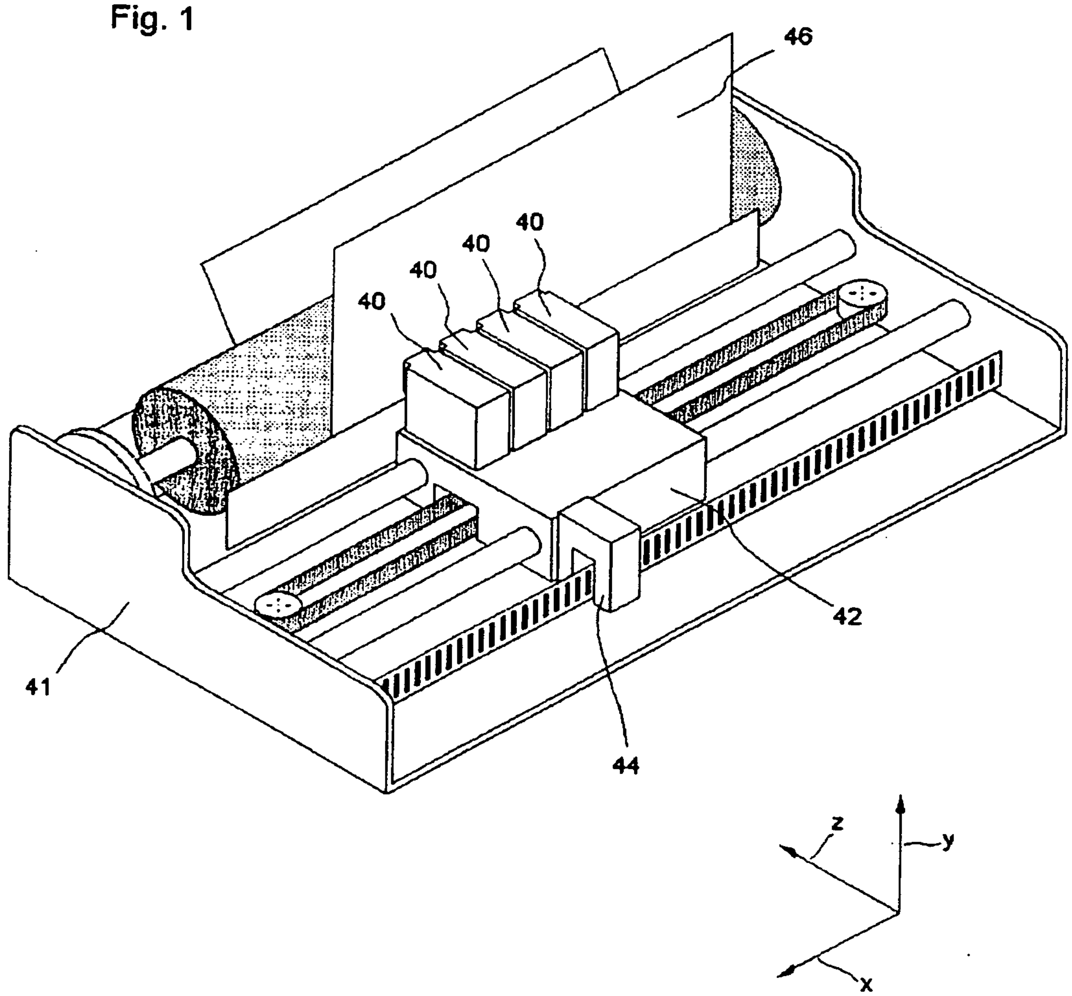


Fig. 2

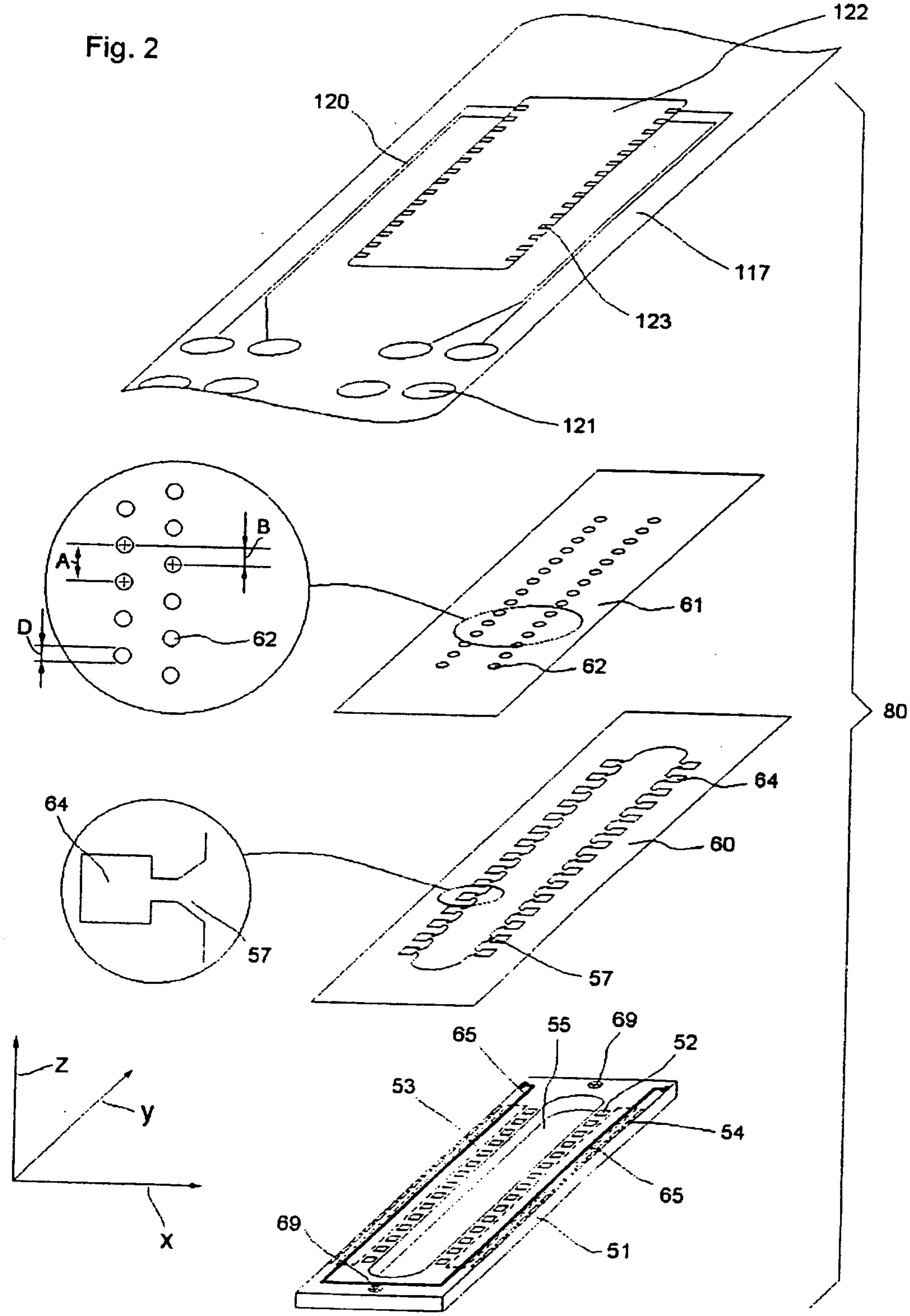

122
120
117
123
121
B
A
D
62
61
62
80
64
64
60
57
57
65
55
69
52
53
54
65
69
51
z
y
x

Fig. 3

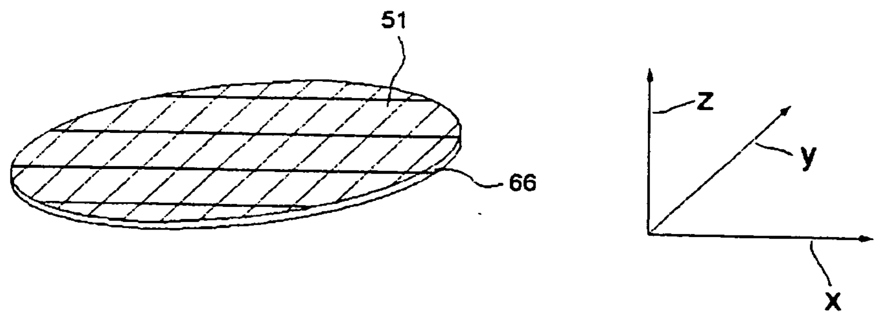


Fig. 5

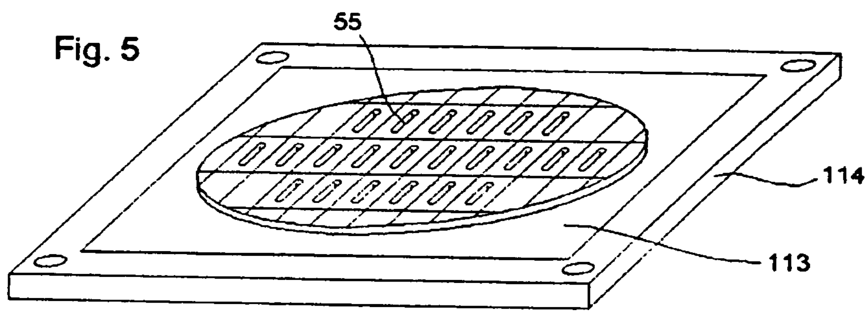
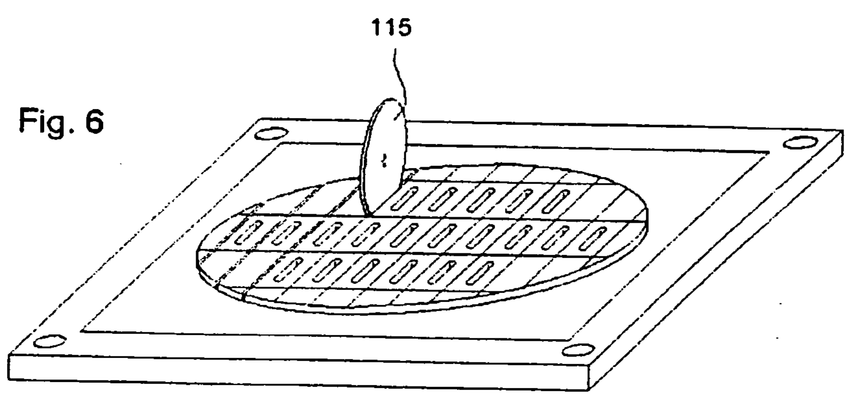


Fig. 6



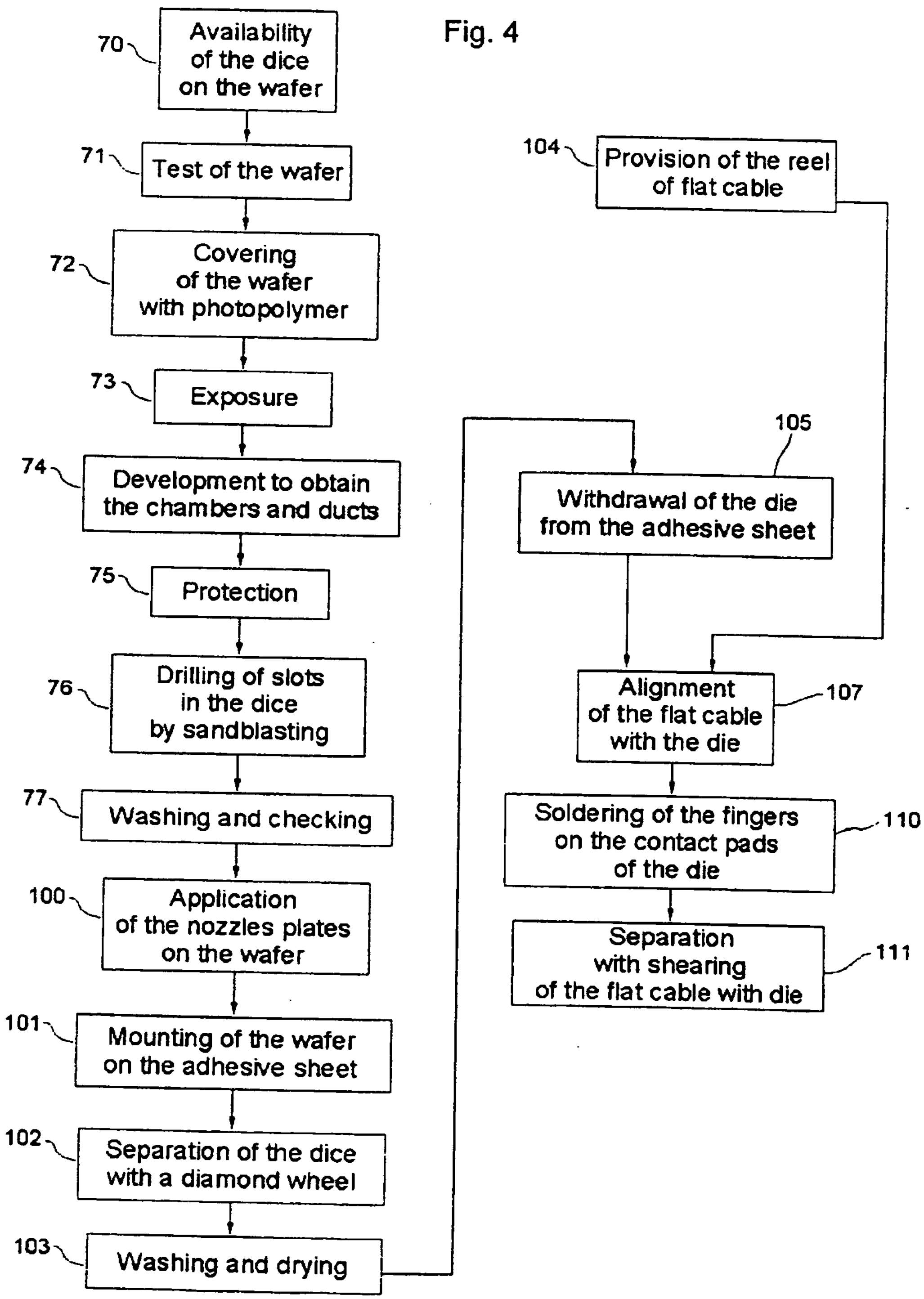

Availability of the dice on the wafer
70
Test of the wafer
71
Covering of the wafer with photopolymer
72
Exposure
73
Development to obtain the chambers and ducts
74
Protection
75
Drilling of slots in the dice by sandblasting
76
Washing and checking
77
Application of the nozzles plates on the wafer
100
Mounting of the wafer on the adhesive sheet
101
Separation of the dice with a diamond wheel
102
Washing and drying
103
Provision of the reel of flat cable
104
Withdrawal of the die from the adhesive sheet
105
Alignment of the flat cable with the die
107
Soldering of the fingers on the contact pads of the die
110
Separation with shearing of the flat cable with die
111

Fig. 4

Fig. 7

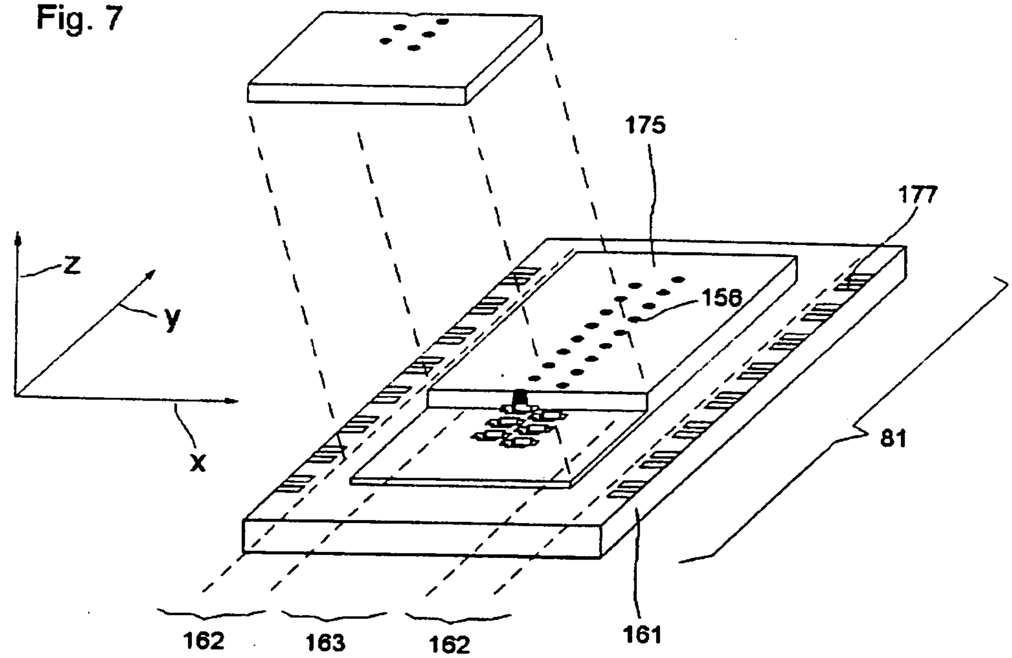
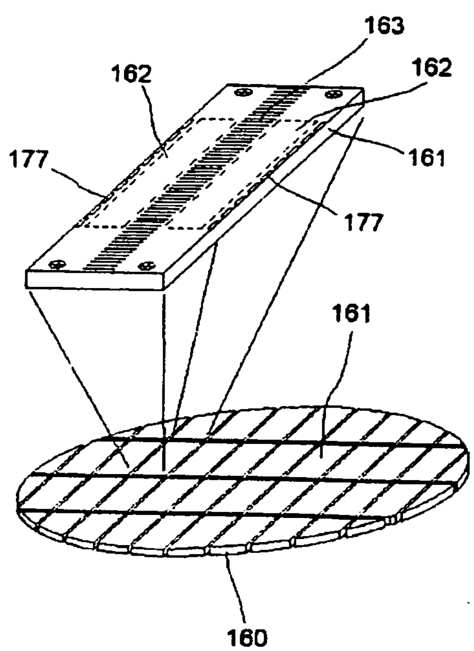

z
y
x
175
177
156
81
162
163
162
161

Fig. 8


163
162
162
177
161
177
161
160

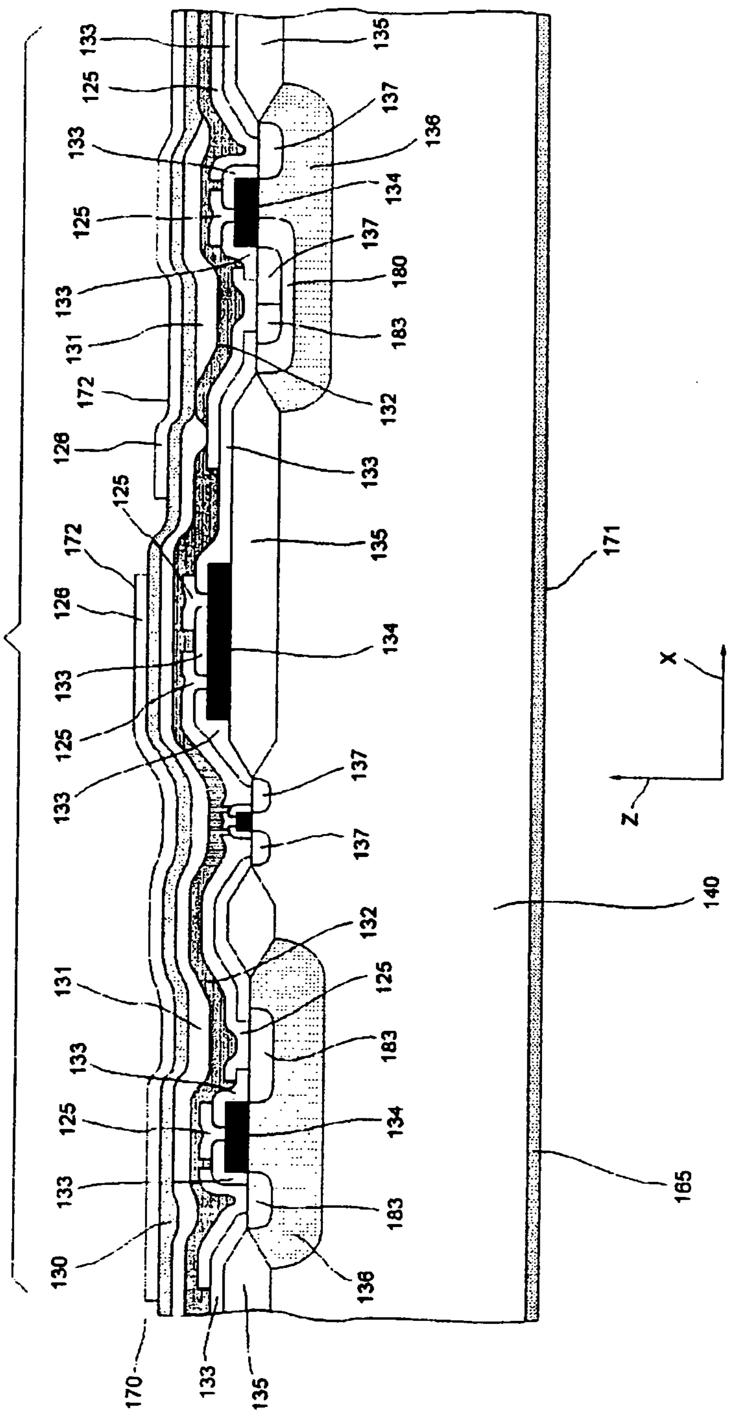
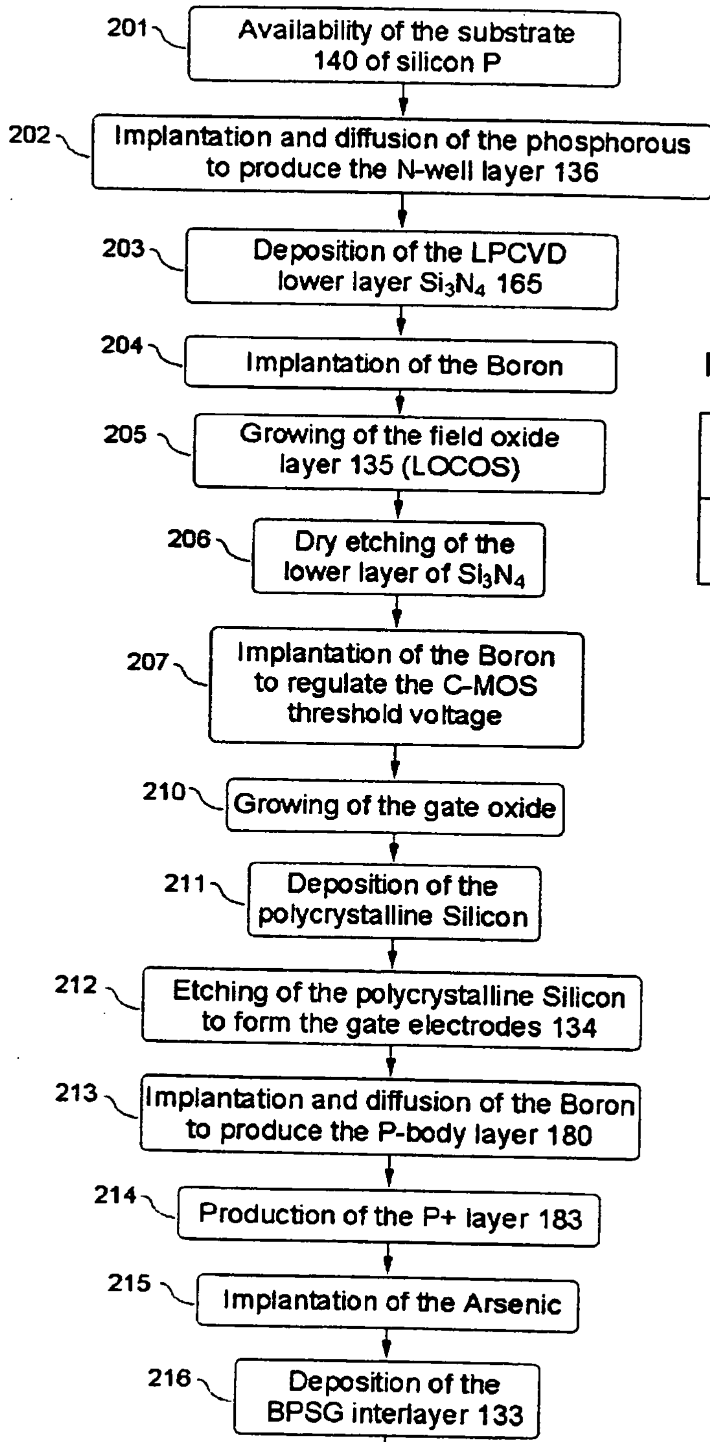

133
125
135
137
136
134
180
183
131
172
128
132
162
140
171
165
170
130
X
Z

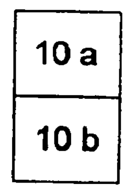
Fig. 9

Fig. 10 a



Contd. at step 217 of Fig. 10b

Fig. 10



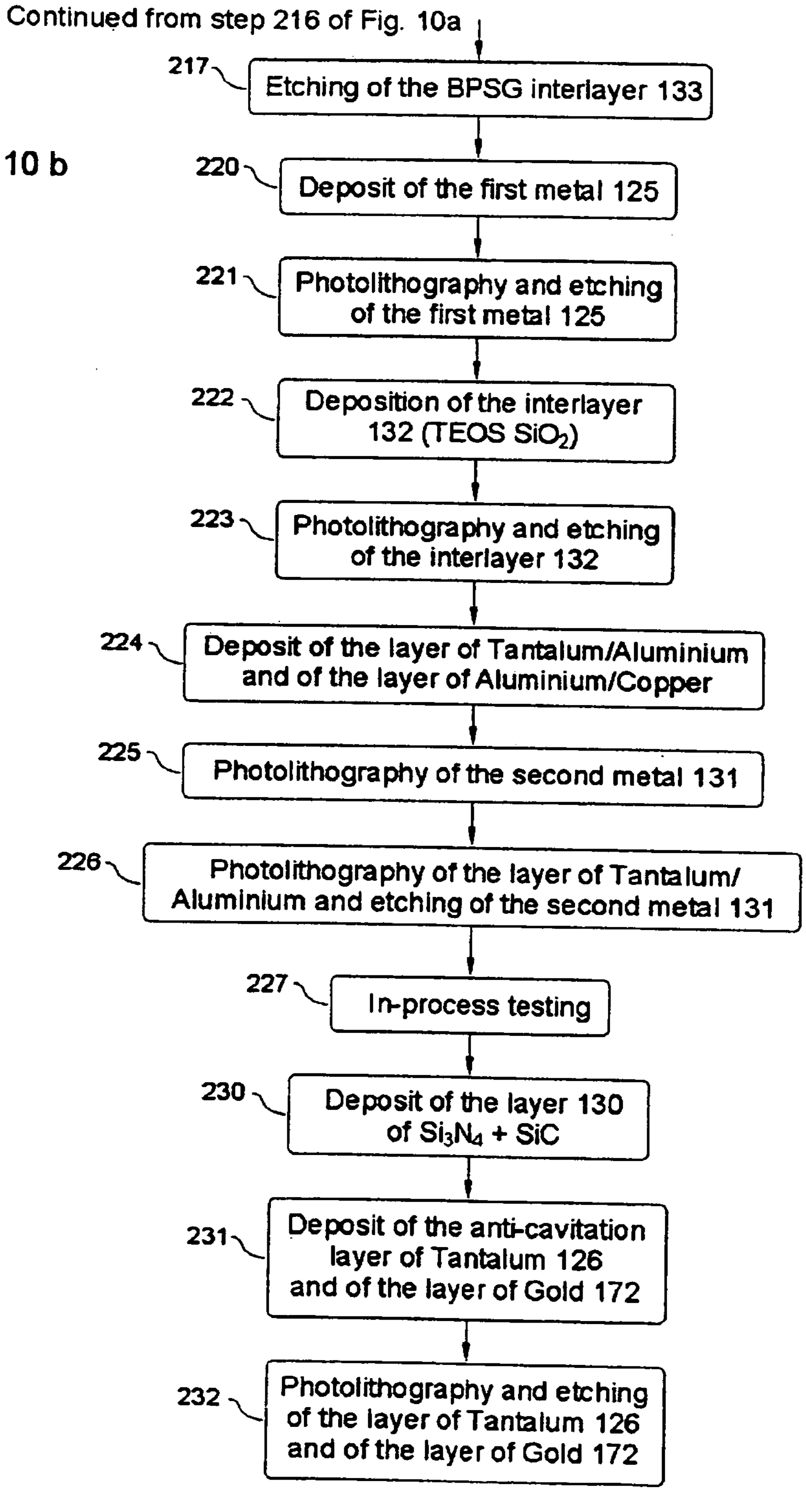

Continued from step 216 of Fig. 10a
217
Etching of the BPSG interlayer 133
220
Deposit of the first metal 125
221
Photolithography and etching of the first metal 125
222
Deposition of the interlayer 132 (TEOS SiO_2)
223
Photolithography and etching of the interlayer 132
224
Deposit of the layer of Tantalum/Aluminium and of the layer of Aluminium/Copper
225
Photolithography of the second metal 131
226
Photolithography of the layer of Tantalum/ Aluminium and etching of the second metal 131
227
In-process testing
230
Deposit of the layer 130 of Si_3N_4 + SiC
231
Deposit of the anti-cavitation layer of Tantalum 126 and of the layer of Gold 172
232
Photolithography and etching of the layer of Tantalum 126 and of the layer of Gold 172

Fig. 10 b

Fig. 11

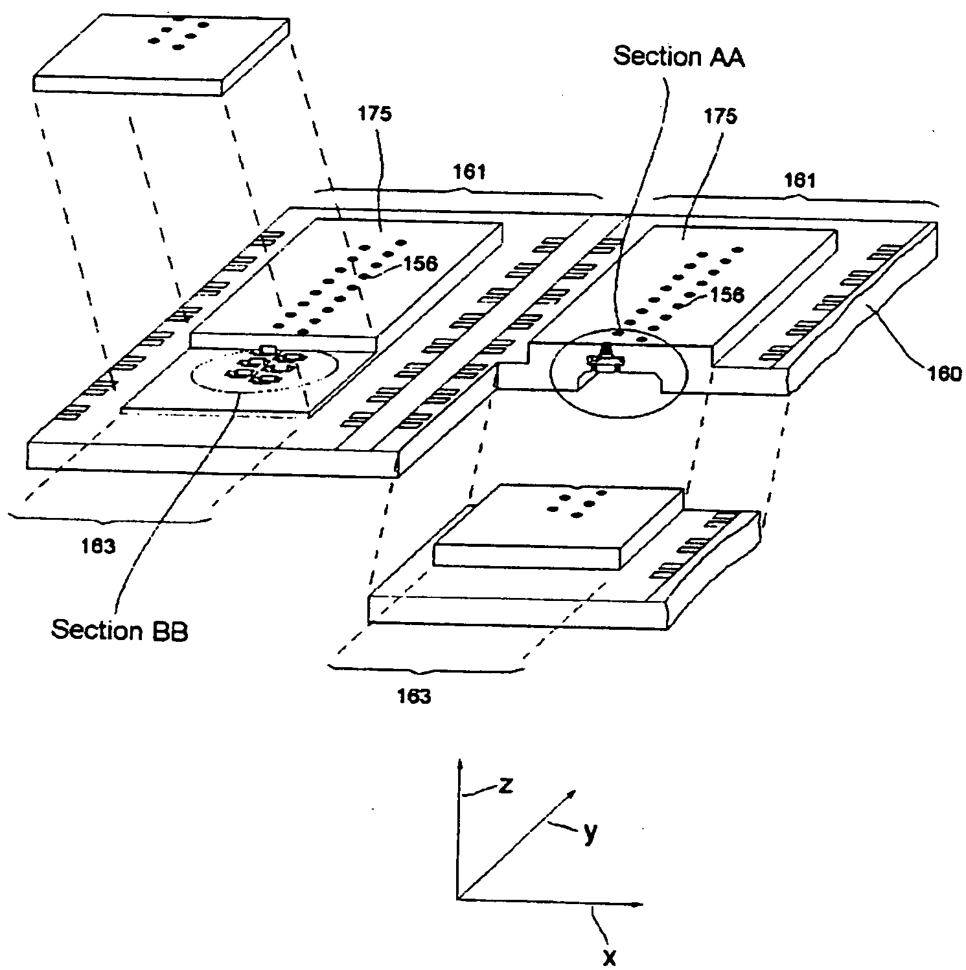


Fig. 12

Section AA

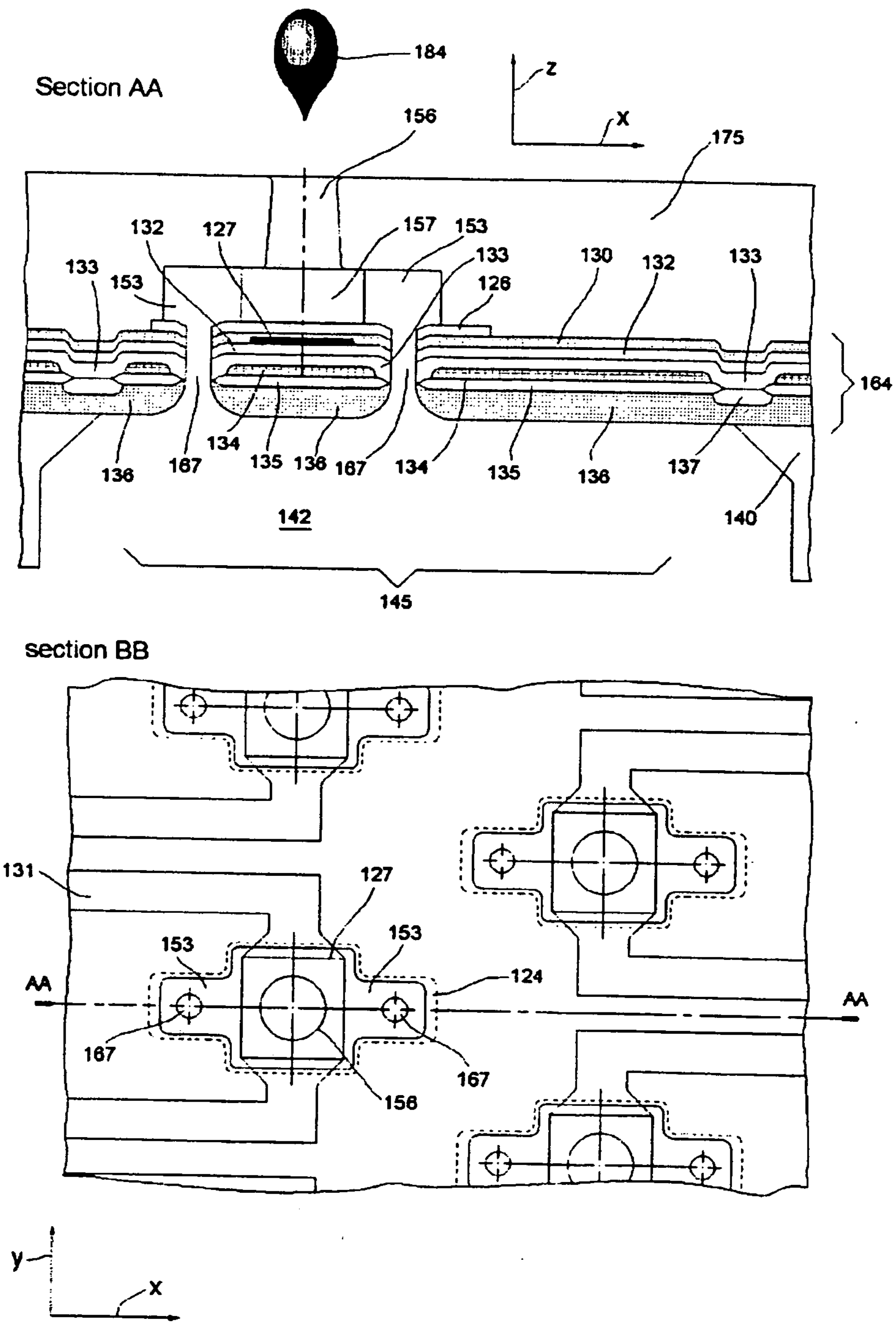


Fig. 13

section BB'

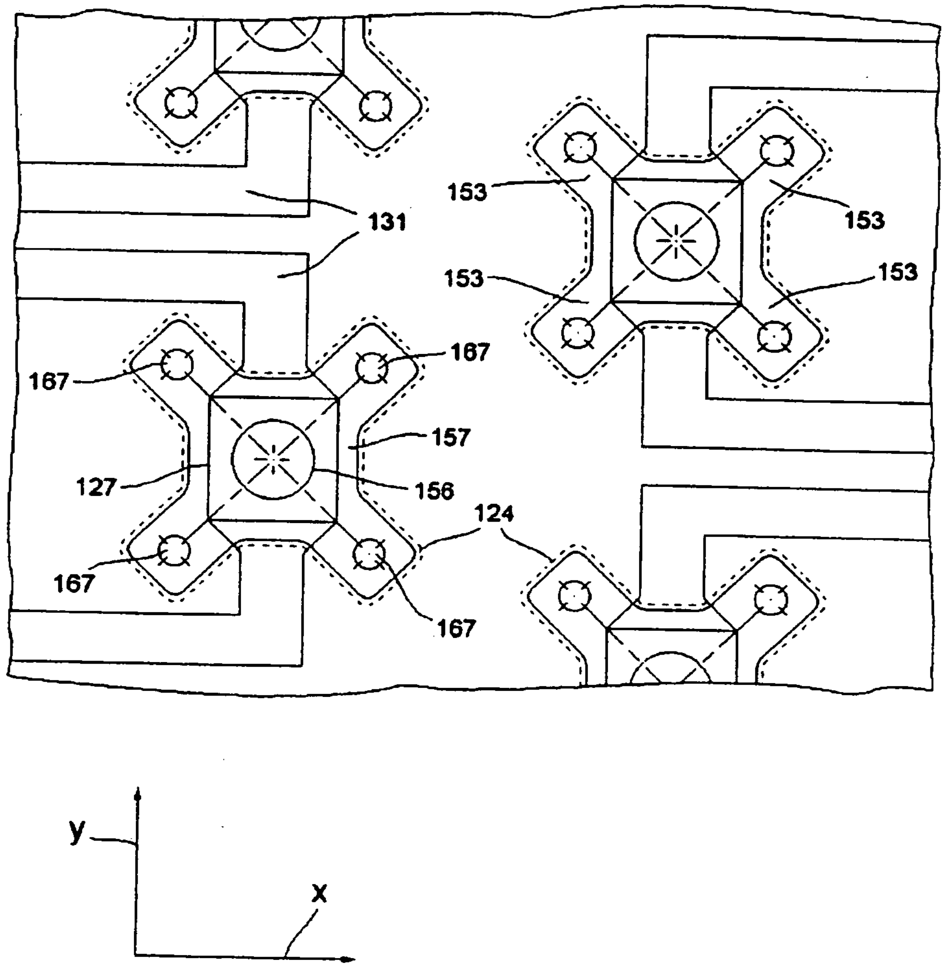
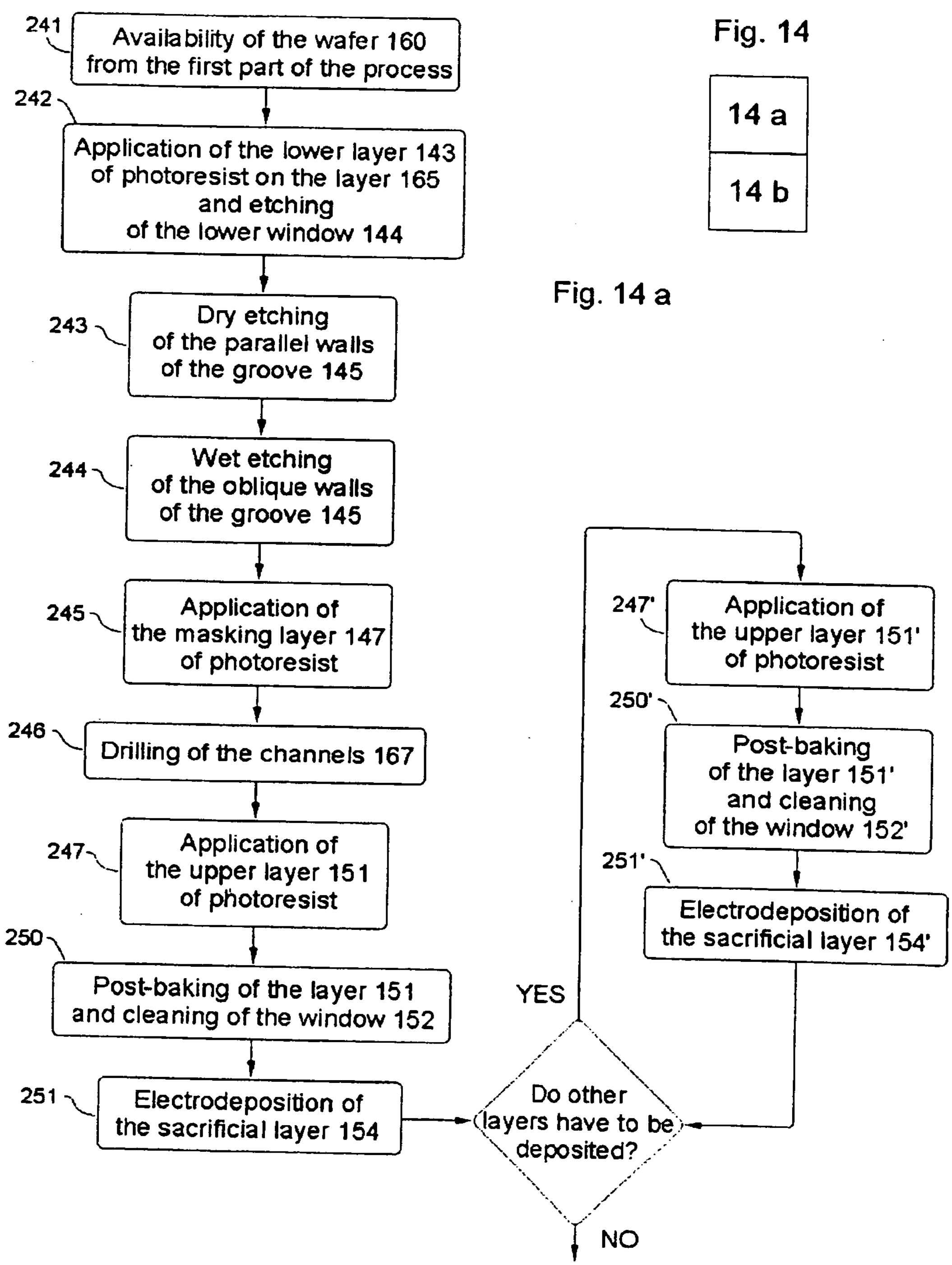


Fig. 14

14 a

14 b

Fig. 14 a



Contd. at step 252 of Fig. 14 b

Continued from step 251 of Fig. 14a

Fig. 14 b

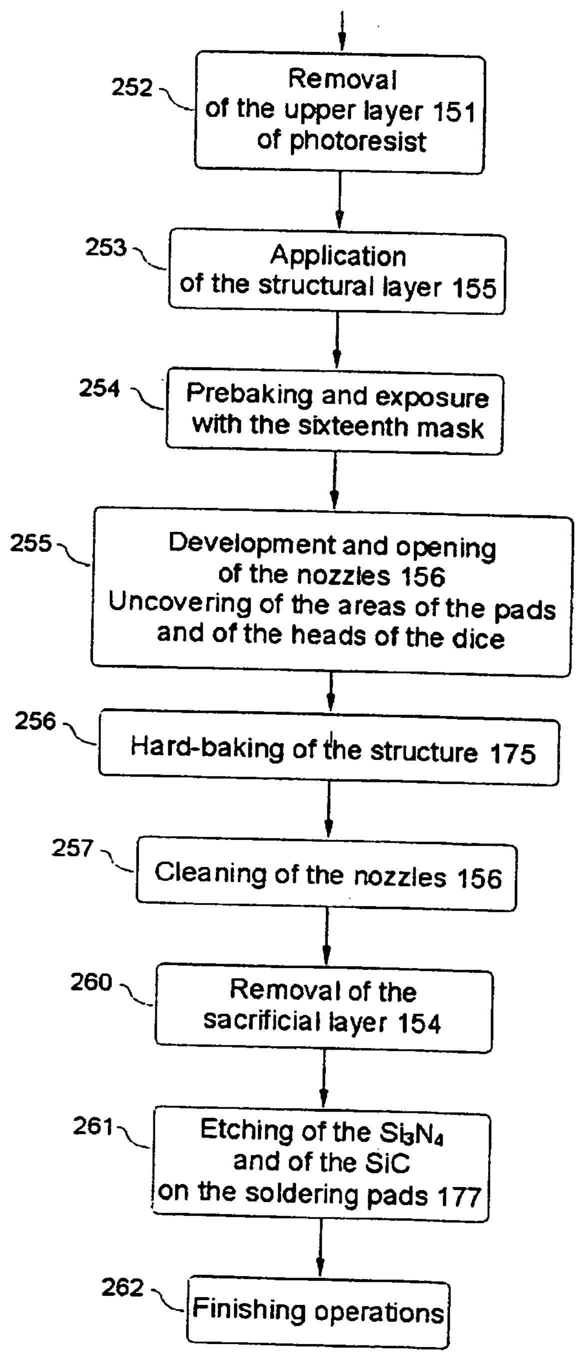


Fig. 15

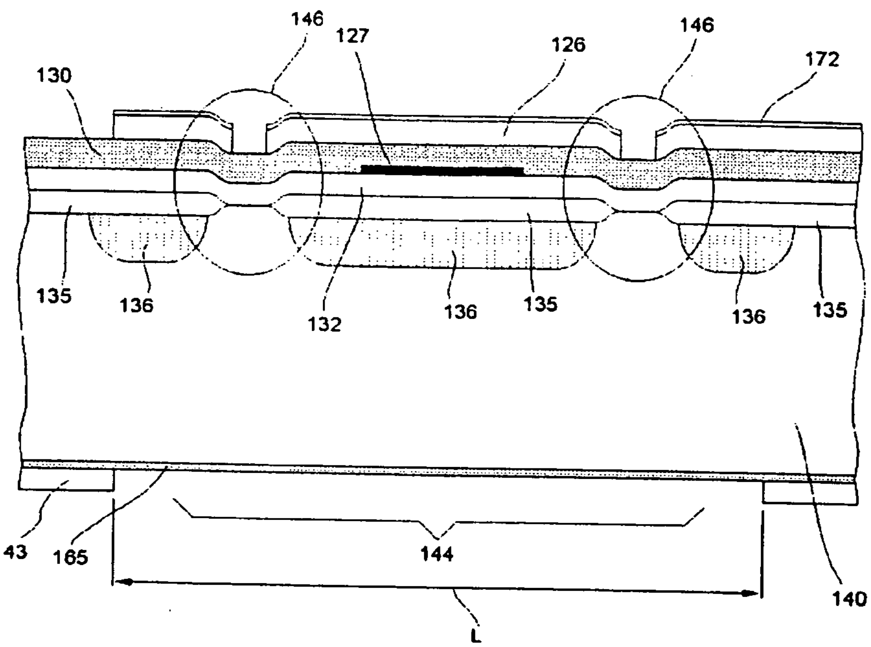

146
127
126
146
172
130
135
136
132
136
135
136
135
143
165
144
140
L

Fig. 16

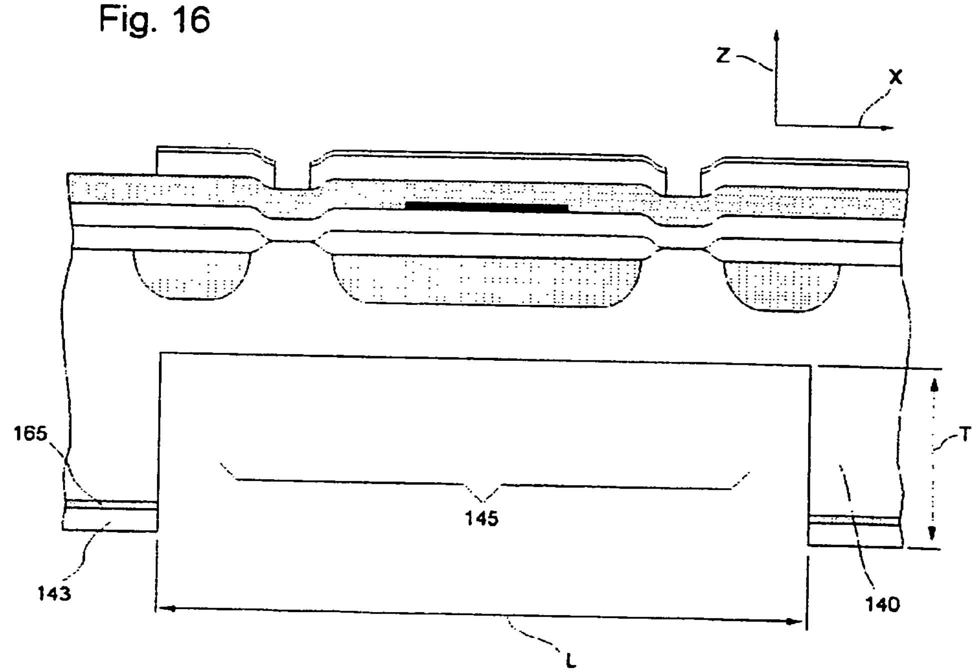

Z
X
165
145
T
143
140
L

Fig. 17

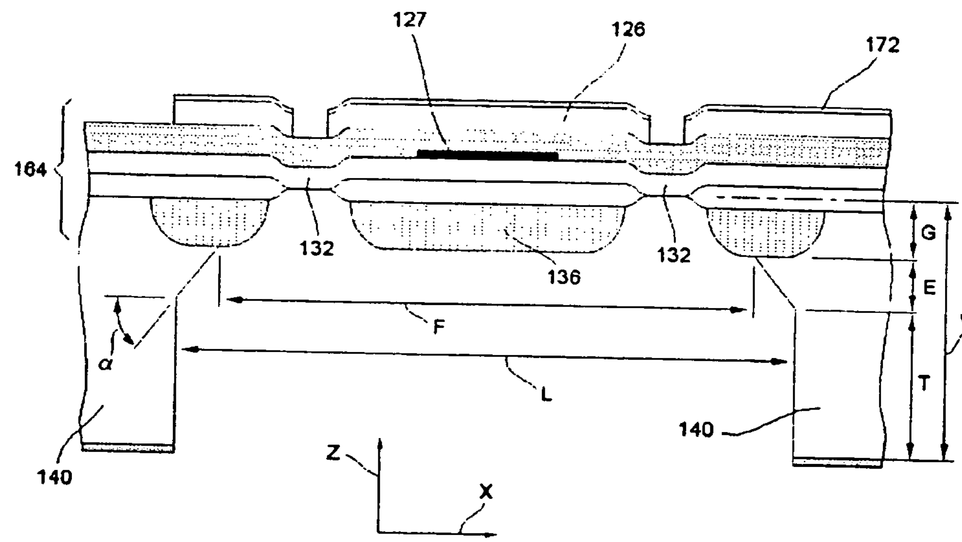

127
126
172
164
132
136
132
G
E
W
F
T
α
L
140
140
Z
X

Fig. 18

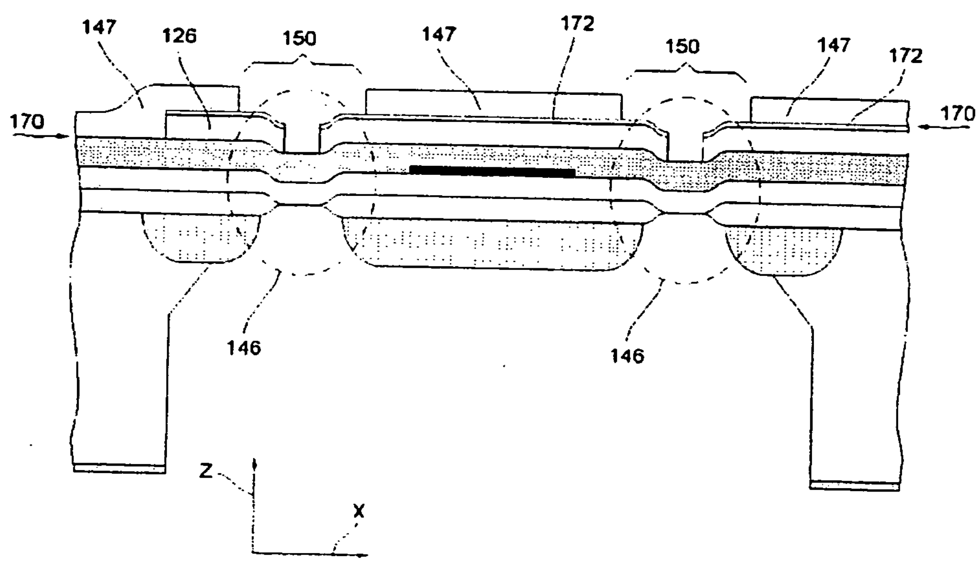

147
126
150
147
172
150
147
172
170
170
146
146
Z
X

Fig. 19

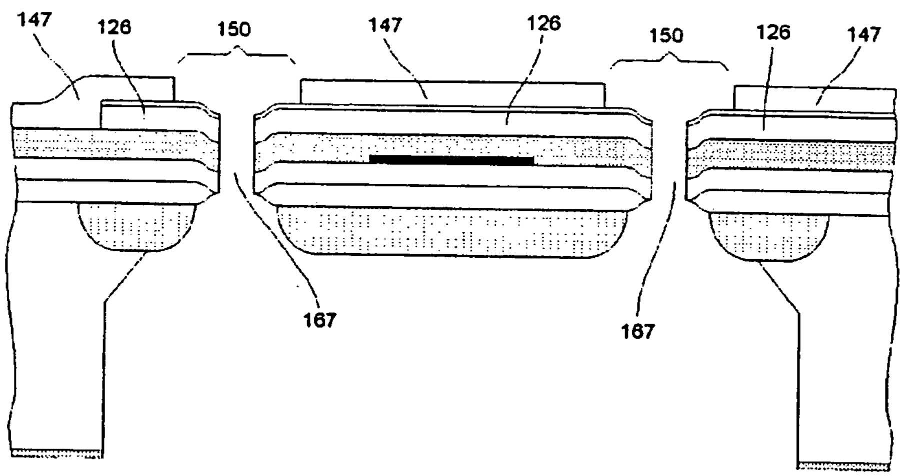


Fig. 20

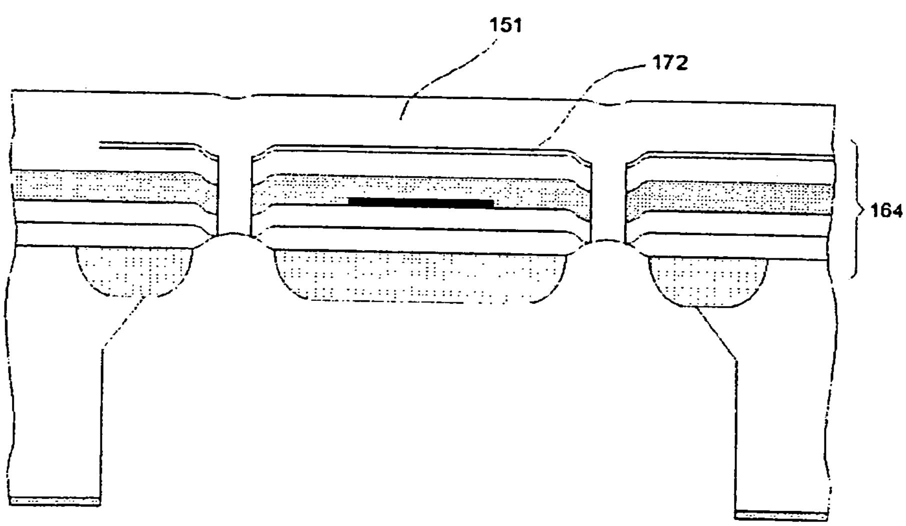


Fig. 21

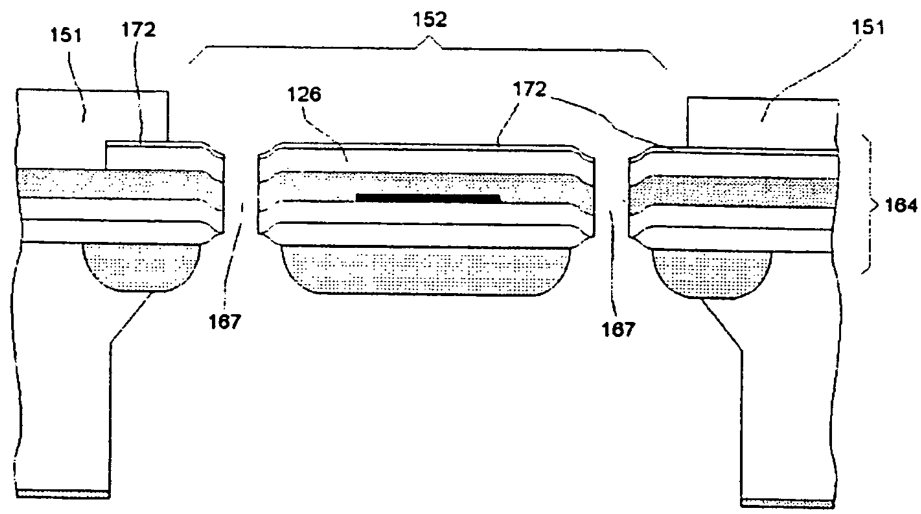


Fig. 22

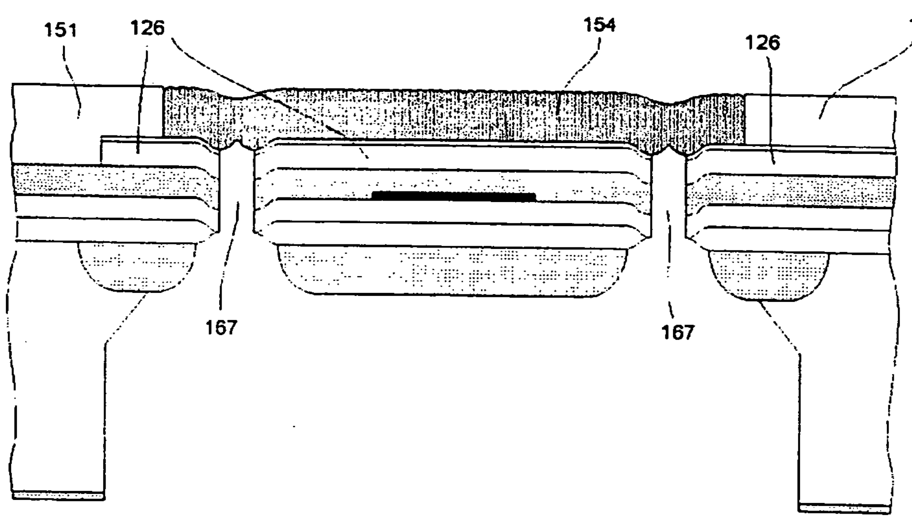


Fig. 23

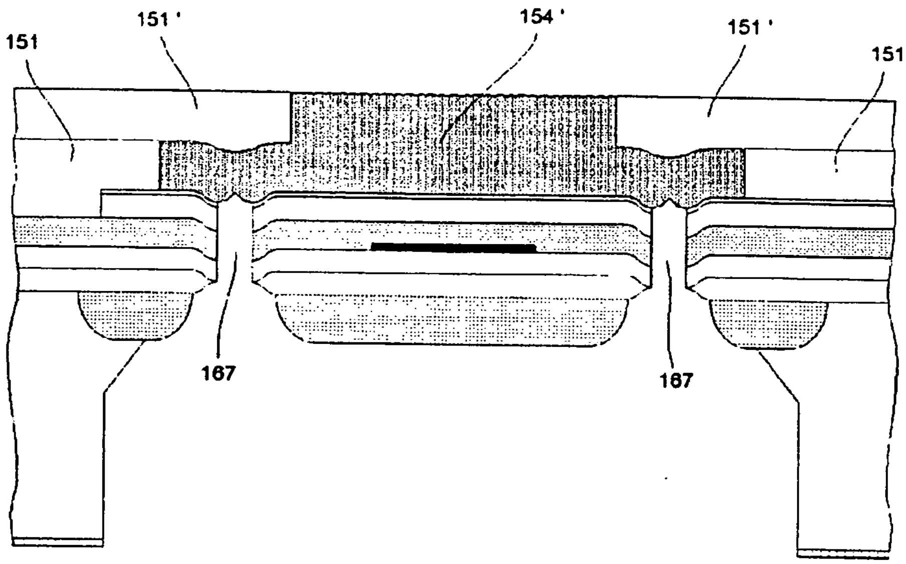


Fig. 24

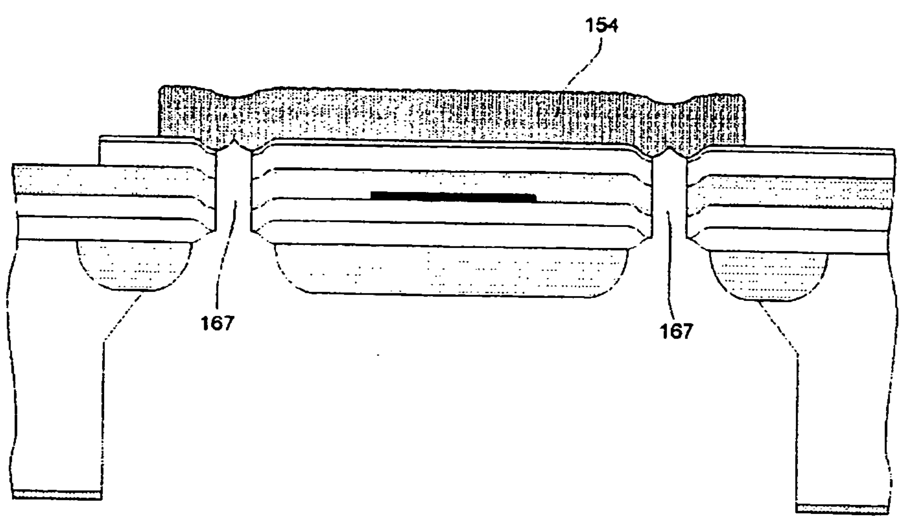


Fig. 25

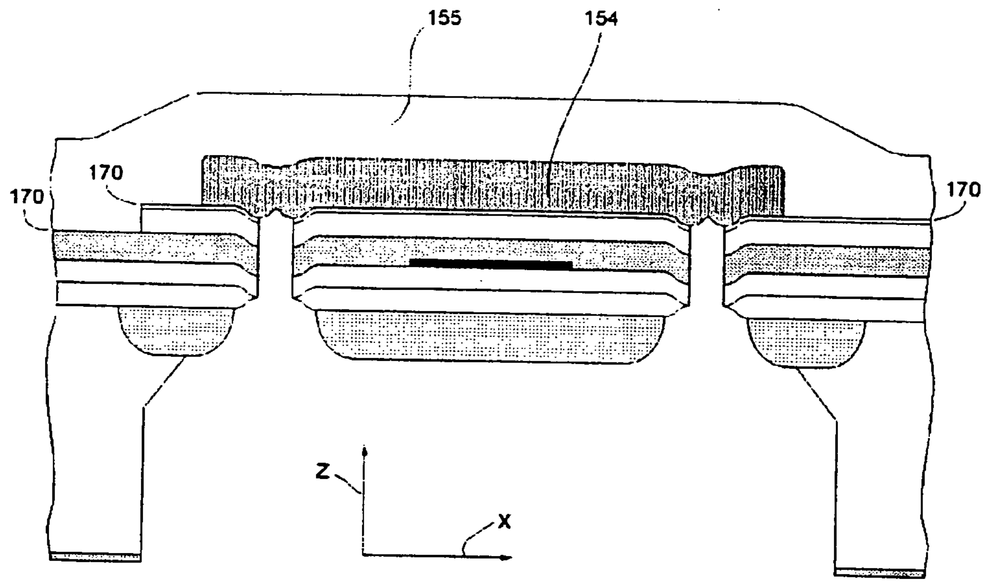

155
154
170
170
170
z
x

Fig. 26

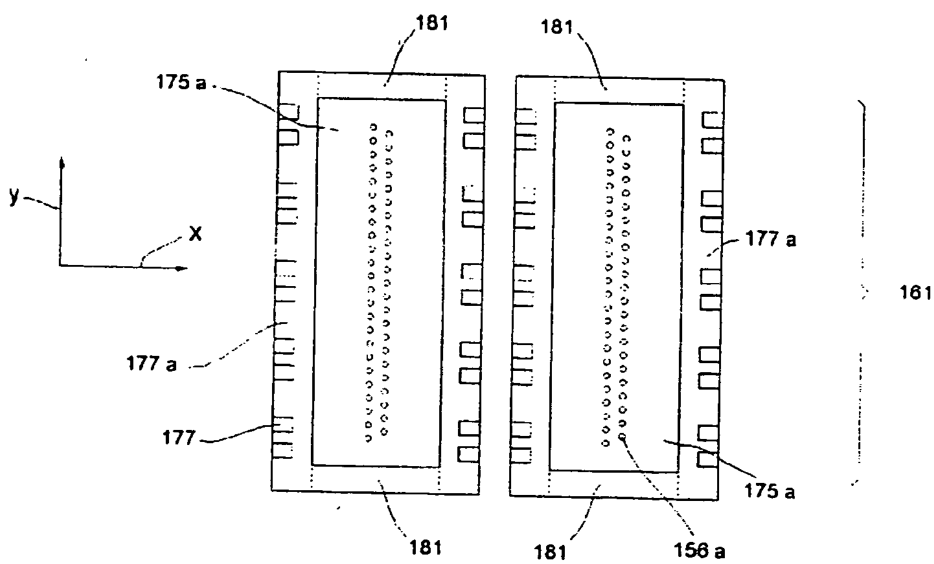
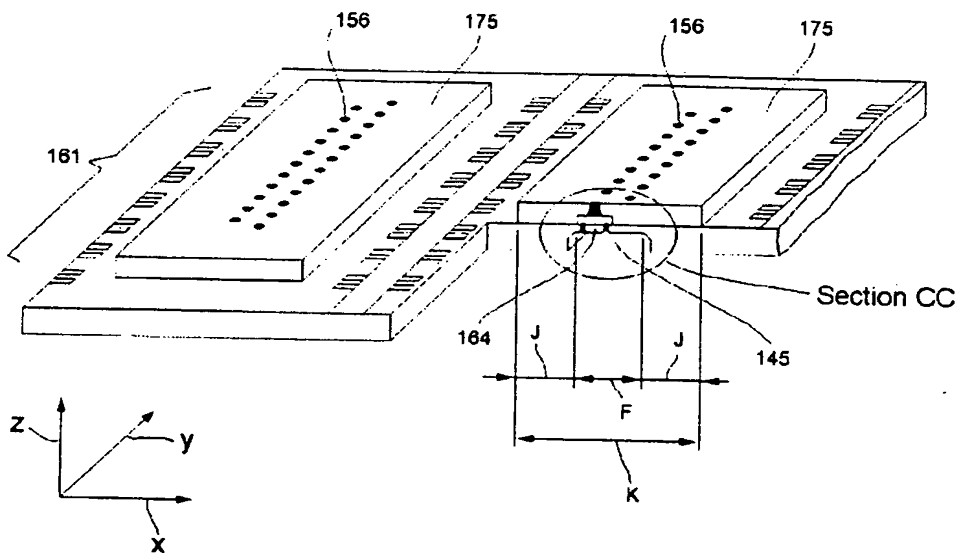

181
181
175 a
y
x
177 a
161
177 a
177
175 a
181
181
156 a

Fig. 27



Section CC

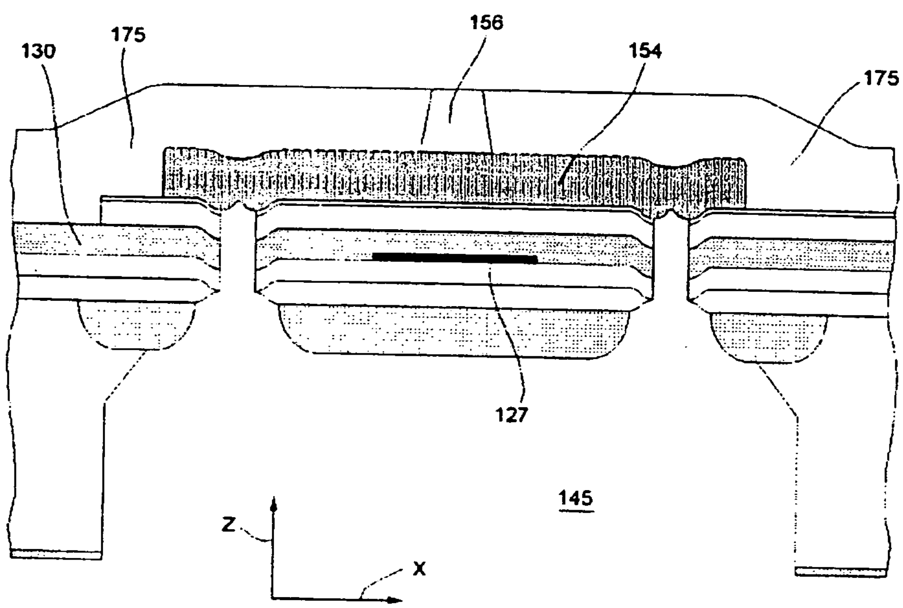


Fig. 28

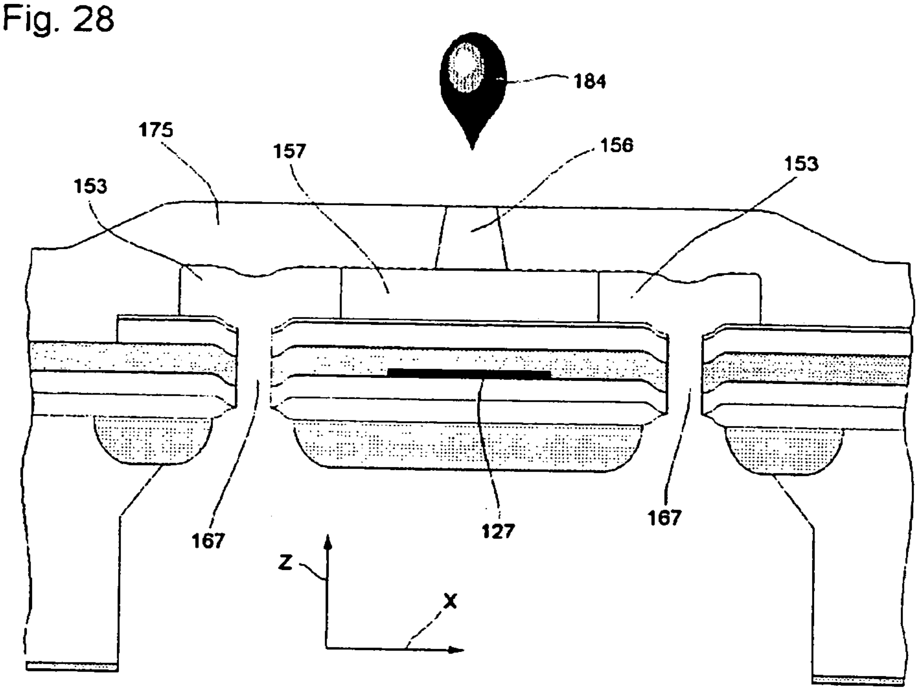

184
175
157
156
153
153
167
127
167
z
x

Fig. 29

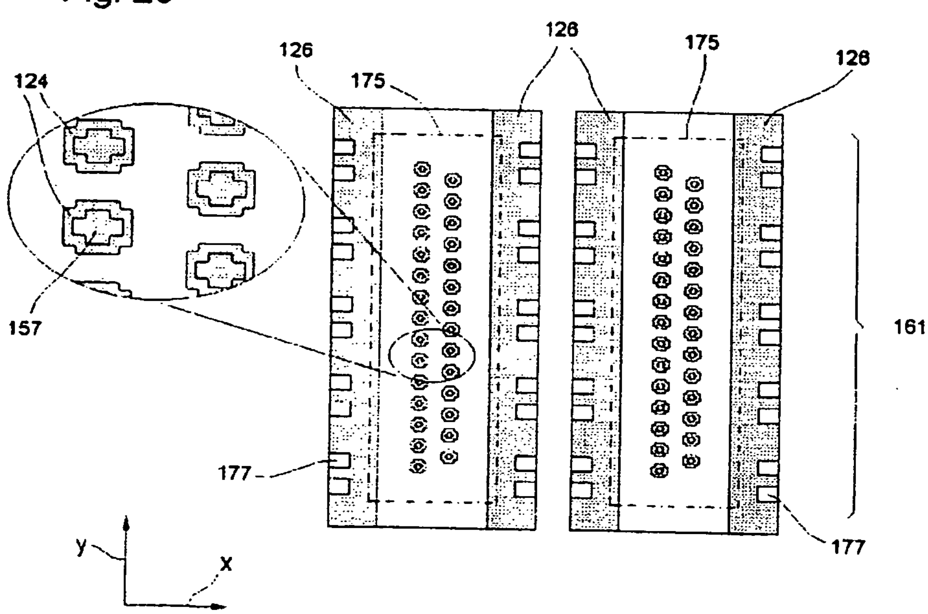
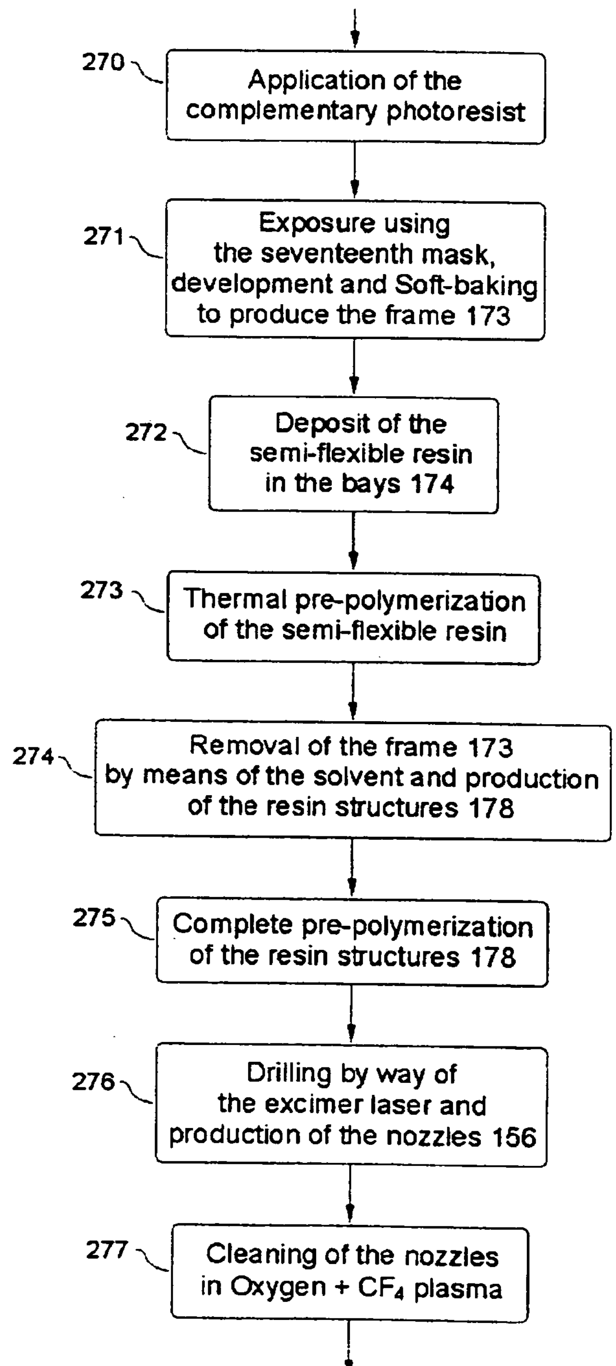

126
128
175
128
124
175
157
161
177
177
y
x

Fig. 30

Continued from step 252 of Fig. 14b



Contd. at step 260 of Fig. 14 b

Fig. 31

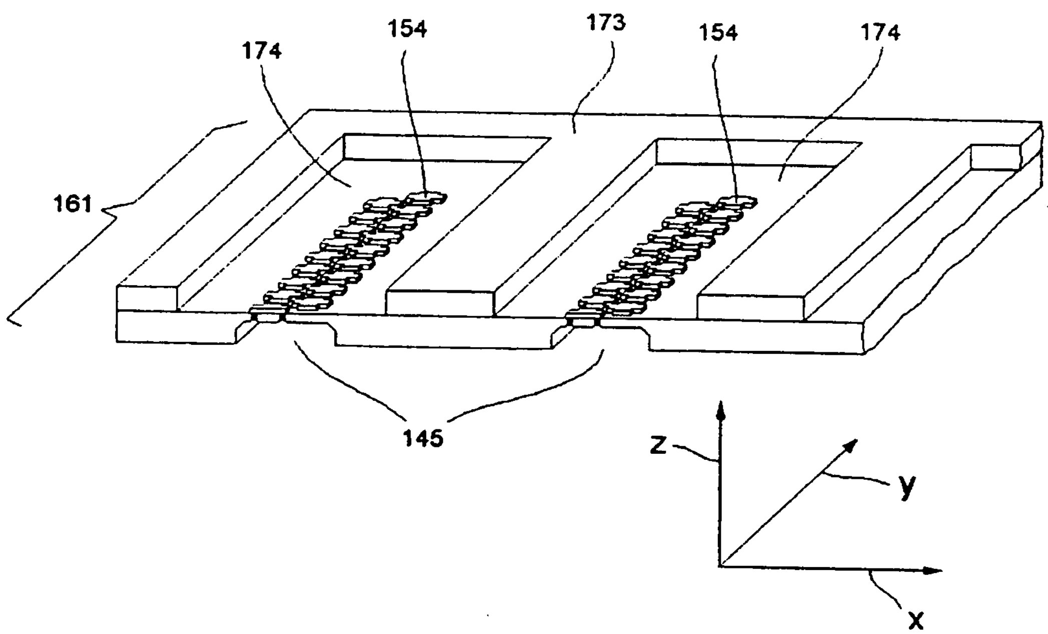

174
154
173
154
174
161
145
z
y
x

Fig. 32

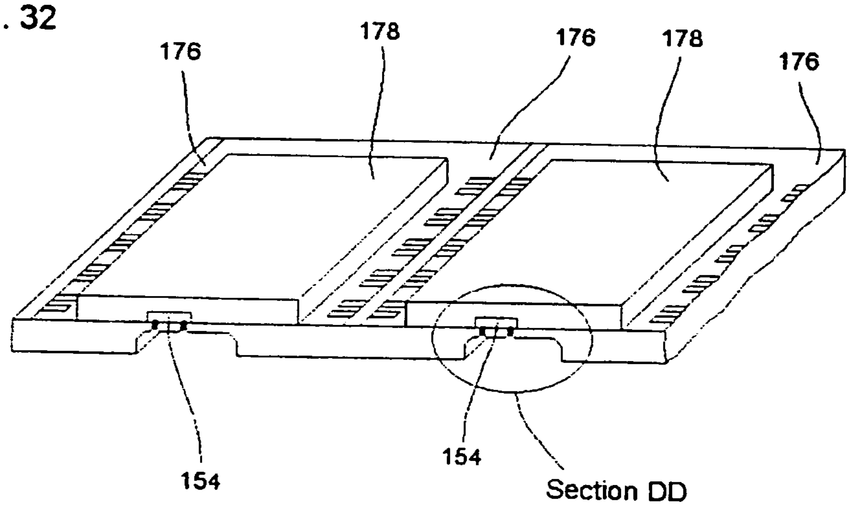

176
178
176
178
176
154
154
Section DD

Fig. 33

Section DD

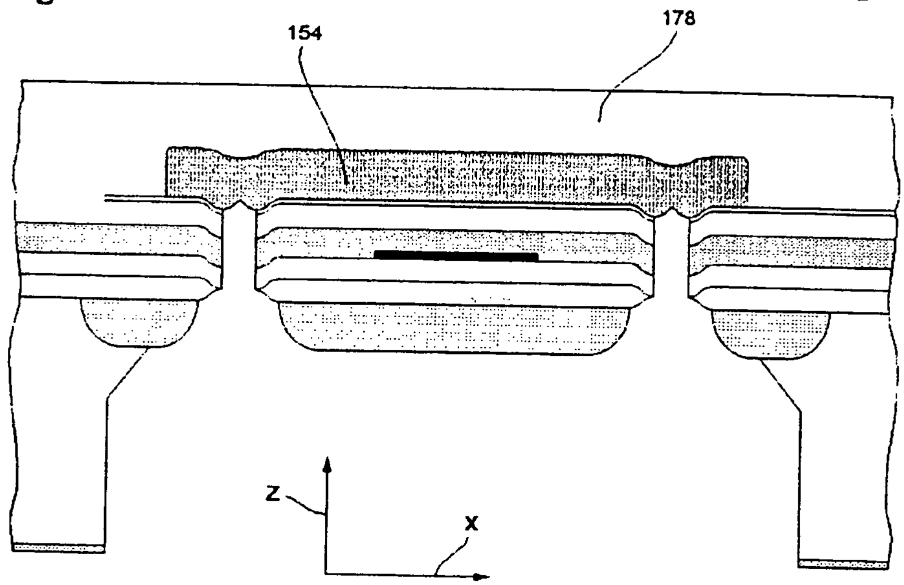


Fig. 34

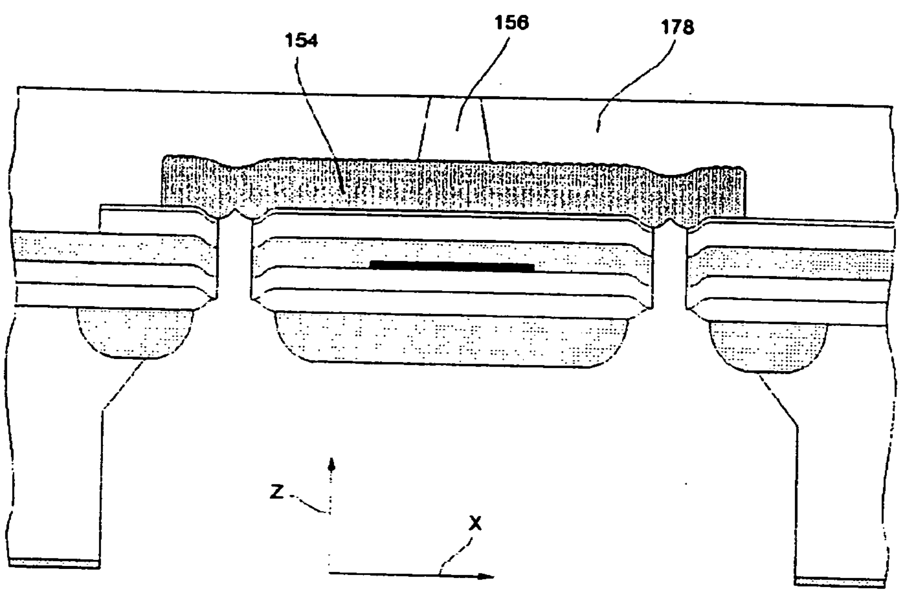


Fig. 35

Continued from step 246 of Fig. 14a

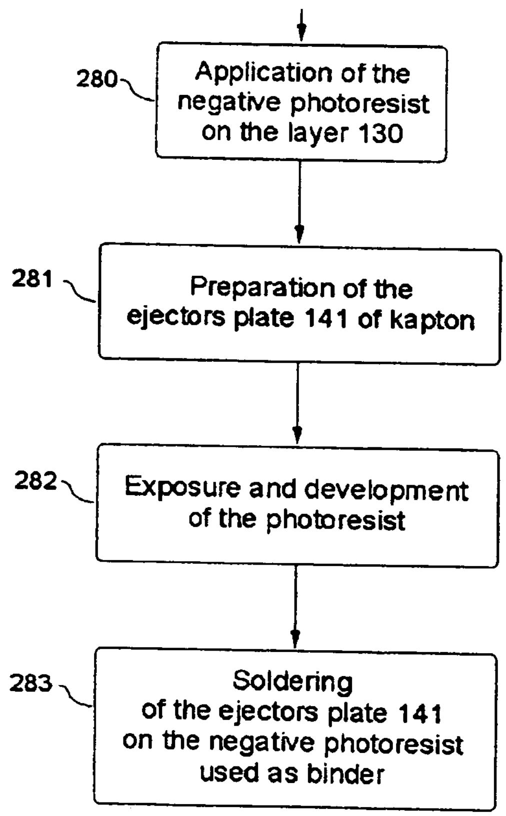


Fig. 36